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UNIVERSITY OF ALBERTA

THE PERFORMANCE OF RELATIVE HUMIDITY TRANSMITTER AND CONTROLLER IN ANIMAL HOUSING

BY

HONG HAO

©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE

DEPARTMENT OF AGRICULTURAL ENGINEERING

EDMONTON, ALBERTA

SPRING 1992

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P. C. Clark

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DATE 06 FEB 92

ABSTRACT

The performance of two types of relative humidity (RH) sensors and a modified moisture control system were evaluated in an animal environment.

The accuracy and reliability of the two types of thin film RH sensor (HT-220 and HT-46) were tested against a reference RH which was calculated by using an accurate dew point temperature and dry bulb temperature. The two RH sensors were monitored over a 7-week period in broiler chicken environments and a 7-week period in turkey housing conditions. Both sensors provided RH measurements which were within 3.6 %RH of readings made with the reference source.

Signal drifts from the two sensors were observed during the experiment. The largest drift was in the final week of each trial. In the broiler trial, the largest drift was 2.0 %RH for the HT-220 and 2.5 %RH for the HT-46 sensor. The data from the turkey trial show that the readings drifted by 3.3 %RH and 3.6 %RH for HT-220 and HT-46 respectively. Both sensors illustrated that, with increased exposure time in animal environments, there was a tendency to read higher than the reference source.

A computer-based moisture control system was implemented by modifying a temperature-based fan controller (T731A Modufan). The temperature sensor of the T731A controller was replaced by a Field Effect Transistor (FET). The FET

was operated by analog signals from a computer-controlled interface board to simulate the performance of the temperature sensor. During a six-week period of testing in turkey environments, the influence on control performance of the two types of sensors, two RH levels and the sensor exposure time were evaluated based on a Controller Performance Index (CPI) which was defined as RH% Error-Hour. The results illustrated that there were no significant effects on the performance of the RH control system due to sensor type or exposure time. Significant effects were observed due to different control set points for RH levels. The results show that the control system performed better under low RH control set point than a high RH level control set point. The RH control system demonstrated a satisfactory performance under the two RH control set points with an overall observed mean differential of 2.30 CPI for the 6-week testing period.

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1. INTRODUCTION

1.1 Importance of Relative Humidity (RH) Control.

An animal environment is exceedingly complex. It comprises all of the thousands of physical, chemical, and biological factors that surround an animal's body, and each environmental factor may vary over space and time (Esmay, 1983). Moisture content is one of the factors which has been recognized as having a significant effect on an animal's health, performance and productivity.

From the aspect of physiology of animals, moisture content in animal housing has a number of very important influences on animals. Very high or low humidity levels (greater than 90% or less than 30 %RH) are said to be detrimental to animal health (Wathes et al., 1983). The high humidity levels in closed environments could increase the incidence of disease transmission as fine water droplets facilitate the movement of micro-organisms in the air. Sainsbury and Sainsbury (1979) reported that the amount of water vapour in the air also controlled the rate of evaporation of moisture from the external surface of an animal, especially the lungs and respiratory tract.

The moisture content will directly affect the latent heat loss of animals and a high relative humidity will become crucial in influencing an animal's thermoregulatory capacity at high ambient temperatures where sensible heat

loss is limited. Moisture content indirectly effects the performance of animals by affecting air quality through dust and pathogen concentrations. Moisture content has a significant influence on airborne viruses. Wright et al. (1968) reported that the survival of the airborne mycoplasma was found to be best at very low and at very high humidity levels.

For lower temperature conditions (below 10 °C), high relative humidity levels decrease the animal's resistance to body heat losses. This humidity dampens the animal's coat as well as the building. In return, this dampening effect reduces the thermal resistance of the animal's skin and exposes it to high rates of heat loss (Sainsbury and Sainsbury,1967). Also the moisture can damage building components (Holmberg, 1972).

Moisture control in mechanically-ventilated livestock environments during cold weather is usually accomplished indirectly by controlling temperature. The direct control of relative humidity in animal housing is usually not available because humidity measurements can be hampered by air contaminants in such an environment.

The ventilation requirements for a particular livestock housing situation can be shown by the ventilation graph in Figure 1. The graph describes the required ventilation rate as a function of outdoor temperature according to temperature and humidity control criteria. Sensible energy

and mass balances are used to determine the relationship between ventilation rate and outside air temperature based on these criteria.

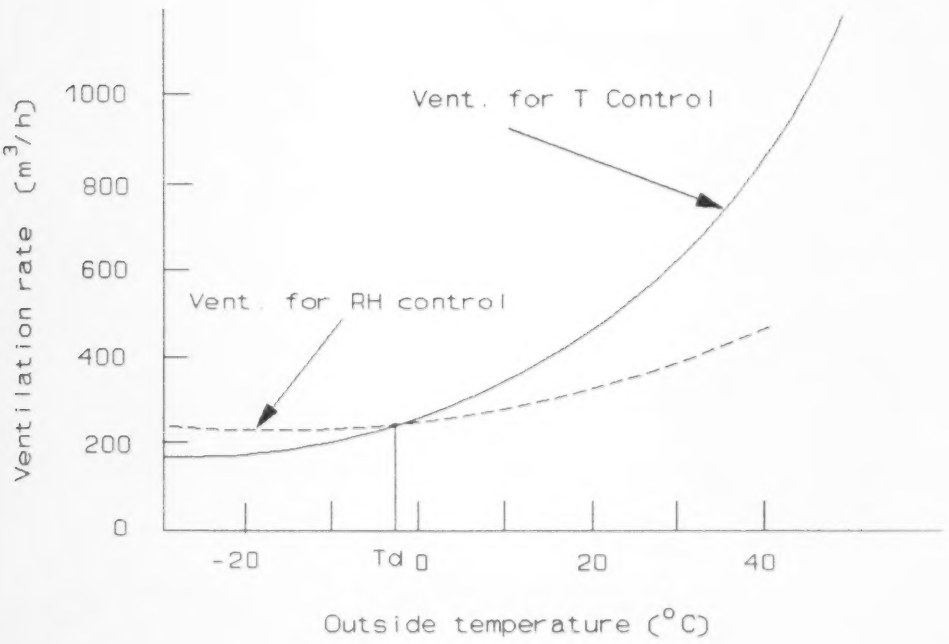

Figure 1 Ventilation Graph

Mature animals normally produce sufficient body heat to permit ventilation with no need for supplemental heat during typical cold weather (Albright, 1990), but at certain temperature the animals cannot produce sufficient body heat to maintain an adequate temperature in the building at the minimum ventilation rate without supplemental heat, this

temperature is defined as heat deficit temperature (T_d). To determine minimum ventilation rates for animal housing, factors in addition to air temperature must be considered and criteria arising from various factors may conflict. Humidity and other air contaminants may increase when the ventilation rate is low to the point where they dictate the minimum ventilation rate. If that happens, it may no longer possible to maintain air temperature at the desired level without supplemental heat (Albright, 1990). For outside temperature below T_d, humidity becomes a dominant factor for ventilation control. A good heating and ventilating control system should cause a ventilation rate to change such that the rate achieved closely follows the uppermost curve in Figure 1.

The minimum ventilation rate for animal housing during the heating season is usually based on the moisture production within the airspace. Since T_d changes with the housed animals' age, the minimum ventilation rate varies with an animal's growth. Thus, it becomes more difficult to control minimum ventilation rate only on the basis of the sensed temperature (Zhang et al., 1990). The direct control of humidity in livestock housing has long been recognized as desirable, but, because of sensor limitations, has not been feasible.

1.2 Possibility of moisture control.

In order to control moisture in animal environments, the humidity sensors must be accurate and reliable. Conventional humidity sensors tend to have problems when used in animal environments due to their low accuracy and frequent maintenance requirement. Humidistat generally sold on the market are operated by mechanical sensing devices, such as nylon ribbon sensors. Not only are the mechanisms easily damaged by the gases in animal housing, but because they become coated with dust, they are hard to clean as well (Thornton and Allen, 1986). Aspirated psychrometers have been used successfully to measure relative humidity levels in animal environments as long as they are exposed to filtered air. However, these filters have to be cleaned at regular intervals varying from two weeks to several months, depending on the levels of usage (Mousely and Fryer, 1976).

The thin film polymer capacitance sensors seem to be the best type of electronic device for measurement of air water vapour concentrations. They can be protected against dust with a permeable filter (Erdebil and Leonard, 1988). However, Visscher and Schurer (1985) reported that even these kinds of sensors had a tendency to accumulate moisture and thus, with time, read higher than the actual humidity.

The accuracy and reliability of humidity sensors is a key factor in successful moisture control in animal environments. Therefore, once characteristics of humidity

sensors are quantified, it should be possible to create an ideal controlled climate for animals. This could lead to further development on minimum ventilation rate control strategies as well as clarifying the effects of humidity on animals.

In this research, the moisture content of the air was expressed as relative humidity (RH) which was defined as the ratio of the partial pressure of the water vapour in the moist air (Pw) to the vapour pressure, if the air were saturated with moisture at the same temperature (Ps) and expressed as a percentage (Hellickson, 1983):

$$RH\ (\%) = Pw/Ps * 100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1.1)$$

2. LITERATURE REVIEW

Ross et al. (1988) tested two types of thin film capacitance sensors (Humiditron 801, Rotronics H3C-200S) in animal environments. A response time of 60 seconds for the sensors to reach 95% of change with an ambient air velocity of 1 m/s was reported. In conditions of relative humidity ranging from 30 %RH to 90 %RH, the Humiditron 801 sensors showed reasonably accuracy. It was found that the sensor exhibited a doped condition when exposed to relative humidity higher than 90 %RH, and a very slow recovery from the saturated condition. The Rotronic H3C-200S proved to be a very reliable sensor over a 6-month period of operation. It was suitable for a relative humidity range of 0 to 100 %RH and recovered rapidly from exposure to condensed moisture. However, the data of Ross et al. (1988) also showed that the electronic humidity sensors consistently underestimated the relative humidity by about 5 %RH compared to a sling psychrometer.

The performance of an aspirated psychrometer and three hygrometers in livestock barns was evaluated by Barber and Gu (1989). The devices were monitored over eight weeks in a dairy barn and seven weeks in a broiler barn. The accuracy and the reliability of a shop-built aspirated psychrometer were compared with those of a saturated-salt dew point hygrometer, a variable capacitance electronic hygrometer,

and a mechanical hygrothermograph. It was reported that only the electronic hygrometer failed to provide relative humidity measurements that were within ± 5 %RH of readings made with a reference psychrometer. Dust accumulations did not effect the accuracy of the sensors as much as was expected.

Vosper and Bundy (1979) reported that a lithium-chloride dew point sensor performed effectively over a three month period in a swine nursery and gave measurements of the dew point temperature with an uncertainty of less than ± 1 °C. A replacement with a clean sensor was recommended for every two months.

Erdebil and Leonard (1989) evaluated an aluminum oxide sensor and two types of thin film humidity sensors (Rotronics, Models HT-220 and HT-46) in a simulated animal environment chamber. The effects of dust, ammonia and their interaction on the performance of the thin film sensors were insignificant, but were significant for the aluminum oxide sensor. The average accuracy value of the thin film sensors were 6 %RH and 7 %RH respectively. The hysteresis values ranged from 0 to 13 %RH for thin film sensors and from 0.4 to 8.1 %RH for the aluminum oxide sensor. They concluded that the thin film sensors exhibited faster response than the aluminum oxide sensor, and were resistant to contamination. Negligible signal drift was also concluded from their tests but these conclusions were based on a short

exposure time of the sensors to the simulated environments.

Very few published reports were found that described the performance evaluation of control strategies based on thermal and non-thermal parameter combinations in an animal environment.

A microprocessor based humidity/temperature control system was developed by Vansteelant et al. (1988) to anticipate the interaction between air temperature and relative humidity. Zhang et al. (1990) developed a Humidity Control Index (HCI) for broiler housing aimed at improving control strategies in the design of heating/ventilating systems and managing livestock buildings effectively. It was reported that the HCI could provide information which was needed in the humidity control region. For example, heaters should be controlled by humidistat and fans should be controlled by thermostats when the outside temperature was much lower than the heat deficit temperature.

A thermostat/humidistat control system was tested against a simple thermistor control system by Barrington and Desjardins (1989). These authors indicated that, as long as the humidistat had a response time of less than 60 seconds, the real potential of relative humidity control could be reached satisfactorily. However, no quantitative analysis was given.

Because of the accuracy and the reliability of temperature sensors, current control strategies for minimum

ventilation rate in animal housing usually are temperature-based. If non-thermal parameters could be sensed with equal reliability, more control strategies would be available for animal environment control. In the case of humidity sensors, there was a need to extend laboratory testing (e.g. Erdebil, 1990) into the field. Once the characteristics of humidity sensors operating in polluted environments have been quantified, the active control of humidity in animal environments will be possible.

In order to explore proper control strategies and to compromise between energy efficiency and air quality in animal environments, it is very practical to expand the commonly used thermal control parameter (temperature) to non-thermal control parameter (humidity) or their interaction as the control parameters.

Quantifying the performance of humidity sensors in animal housing could lead to a development of more effective control strategies for animal environments.

3. OBJECTIVES

The objectives of this project were:

(1) To evaluate the performance of two types of thin film polymer relative humidity sensors (HT-220 and HT-46) under broiler chicken and turkey environments.

(2) To modify a temperature-based ventilation rate controller (Honywell T731A Modufan) to provide computer-based ventilation control using RH signals from the RH sensors evaluated above.

(3) To evaluate the performance of the control system in animal environments.

4. FACILITIES AND EQUIPMENT

4.1 Sensors

Based on the work of Erdebil (1990), two thin film polymer relative humidity sensors (Rotronics, Model HT-220 and HT-46) were selected for evaluation. Relative humidity was measured with a hygroscopic polymer film capacitive sensor and temperature was measured with a precision Pt100 RTD packaged with each humidity sensor. A current output (4 mA to 20 mA), linear with RH, was generated by the sensors. Table 1 shows a summary of the manufacturer's specifications for the two sensors.

Table 1 Specifications of the thin film sensors

	Model HT-220	Model HT-46
Accuracy		
0 to 100% RH @77 °F	± 2.0% RH	± 2.0% RH
20 to 130 °F	± 1.0 °F	± 1.0 °F
Linearity		
0 to 100% RH Over 200 °F span	0.7% RH 0.4 °F	0.7% RH 0.4 °F
Typical long term stability (Over 1 year)	≤ 1.0% RH	≤ 1.0% RH
Output signals 0 to 100% RH (linear)	4-20 mA	4-20 mA

There were two specified applications for the two types of sensors. Model HT-220 was designed for fixed installations in industrial applications, whereas the Model HT-46 was designed for clean environments. The temperature and the humidity probes of both sensors were located at the ends of the 200-mm long plastic cylinders which were attached to the signal conditioning circuit housing boxes. In order to protect the sensors from dust, optional filters were used during the whole testing period.

4.2 Reference Instrument.

Reference relative humidity was calculated from the dew point temperature which was measured with a chilled mirror dew point hygrometer (Model HYGRO-M1, General Eastern Instruments, Watertown, Ma.).

The dew point hygrometer provided continuous dew point temperature measurement. It was an accurate fundamental measurement instrument with NBS-traceable calibration.

The operating principles of the hygrometer are illustrated by Figure 2 below.

The amount of water vapour that any non-reacting gas, including air, can hold depends on its temperature. Since the saturated vapour pressure increases with temperature, the higher the temperature, the greater the amount of water vapour that can be present. The dew point is the temperature at which the selected sample of gas is

saturated. Any lowering of the gas temperature below the dew point causes the excess moisture to be deposited on any surface in contact with that gas, which is in thermal equilibrium with the gas. Dew point sensors measure the precise temperature at which condensation occurs on a surface maintained at a closely controlled lowered temperature. The dew point is independent of the temperature of the gas, but does depend on the gas pressure.

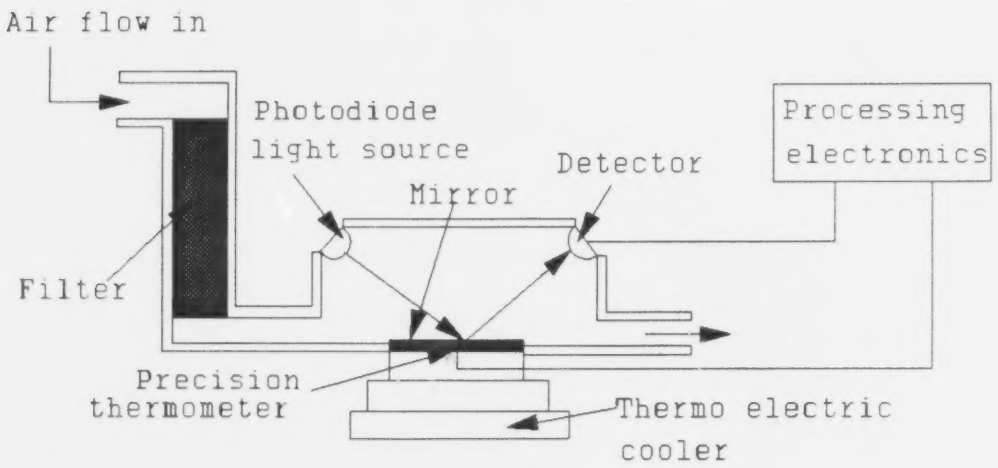

Figure 2 Dew point sensor with mirror detection
(Adapted from Carr-Brion, 1986)

As sample gas passes over the cooled mirror, condensate scatters the reflected light. The reflected light detector senses a drop in light intensity compared to a reference diode pair. The reduction in light drives an optical bridge

away from its balance point. The mirror surface temperature is automatically and continuously controlled at the dew point temperature of the sample gas.

The dew point hygrometer was calibrated by the manufacturer against an NBS-traceable standard and gave outputs between 4 to 20 mA in the range of -40 to +60 °C dew point. The guaranteed accuracy of the instrument was ±0.20 °C. The sensor's response time was 1.5 °C/sec (Anonymous, 1989). The measured air was filtered through a fine metal filter before entering the dew point hygrometer in order to protect the sensor from dust particles.

The reference relative humidity was calculated according to the Antoine Equation (Wood, 1970) which can be expressed as follows:

$$(T_{dp} + C)^{-1} = (T + C)^{-1} + L^{-1} * \mathrm{Log}(RH)^{-1}$$

Where: T_{dp} = Dew point temperature in °C

T = Air space temperature in °C

L = 1750.286 $(°C)^{-1}$

C = 235.0 °C

RH = relative humidity (decimals).

4.3 Data acquisition

4.3.1 Data acquisition and control interface board

An IBM PC was used to run the relative humidity control

program. A Dascon input/output (I/O) expansion board (Metrabyte Corp., Stoughton, Ma.) was used in conjunction with the computer for control and data acquisition. The Dascon board had 4 analog-to-digital (A/D) input channels, 12 digital I/O ports, 2 digital-to-analog (D/A) output channels and 12-bit resolution for A/D and D/A channels (Anonymous, 1983). The software supplied by MetraByte for the Dascon Board was accessed using call statements in BASIC. The subroutines initiated A/D conversion, data transfer to memory, reading or writing data to ports or setting the programmable timer. Once the raw data was stored in the memory of the personal computer, it was retrieved and processed as needed.

4.3.2 Signal condition elements

Signal conditioning circuitry was required to convert the output current from the sensors to voltage signals within the required A/D input voltage range (0 to 2 V). The 0-20 mA sensor outputs were converted to voltages using resistors (100 ohm) in the A/D converter of the Dascon board.

4.3.3 A/D input channel expansion.

As the four A/D input channels from the Dascon board could not meet the demands of the sensor evaluation application, an eight-channel analog multiplexer (MC 14051B)

and a high speed Dual one-of-four decoder/demultiplexer (SN54/74LS139) were used to expand the four A/D input channels to eight. Figure 3 shows the expanding of channels using the MC 14051B multiplexer.

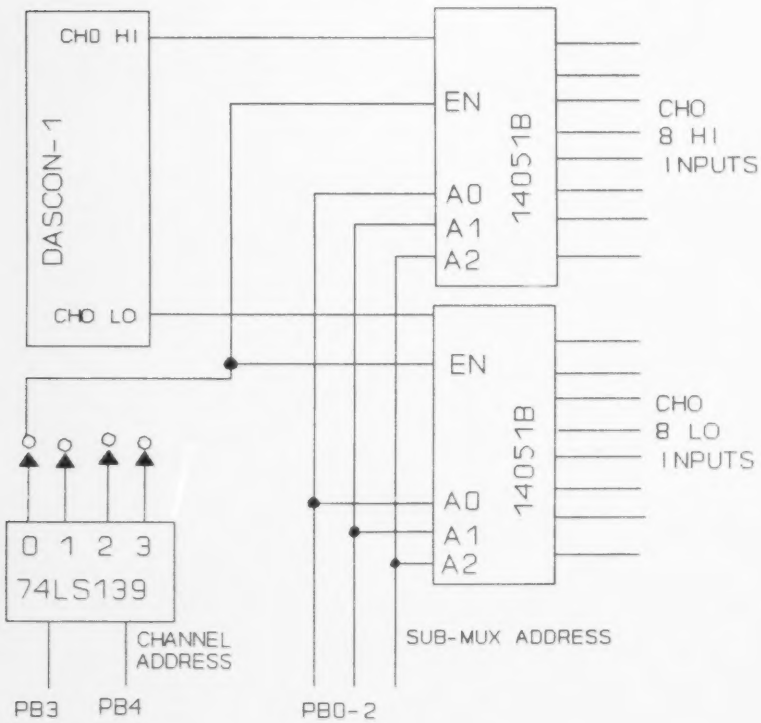

Figure 3 Expanding input channels using MC 14051B Multiplexer

Channel address selection is on PB3 and PB4, and the control signals are from PB3 and PB4 ports of the Board

respectively. The multiplexer will be OR'ed on to PB0-PB2 prior to conversion, and the control signals are coming from PB0-PB2 ports respectively.

4.4 Experimental environment

A field test of the humidity sensors was conducted in a turkey barn at the University of Alberta's Parkland Research Station in Edmonton. The field test was carried out during spring and winter of 1990-1991.

The experimental units were equipped with a constant temperature control system. The system consisted of a hot air duct with a heater installed at the air inlet so that outside air could be heated as it flowed through the air inlet duct to the attic. Air was draw from the attic into four experimental rooms using ventilation fans. The ventilation fans in each room consisted of a variable speed fan (Model SD 12-EV, Canarm Ltd., Brockville, ON.) and a two-speed fan (Model S 8-B2, Canarm Ltd., Brockville, ON.). A 2.8 m long flow measurement duct was installed downstream from each fan.

The variable speed fan in each room was controlled by a T731A Modufan controller (Honeywell, Scarborough, ON.) which could be operated by the modified computer control system. The fans could be operated separately or run together. Each testing unit also had a recirculation duct and a misting system. The misting system could generate different

moisture contents in the air space by injecting water through a spray pipe line. In addition to misting, different relative humidity levels could be achieved by using the two fans to give different ventilation rates.

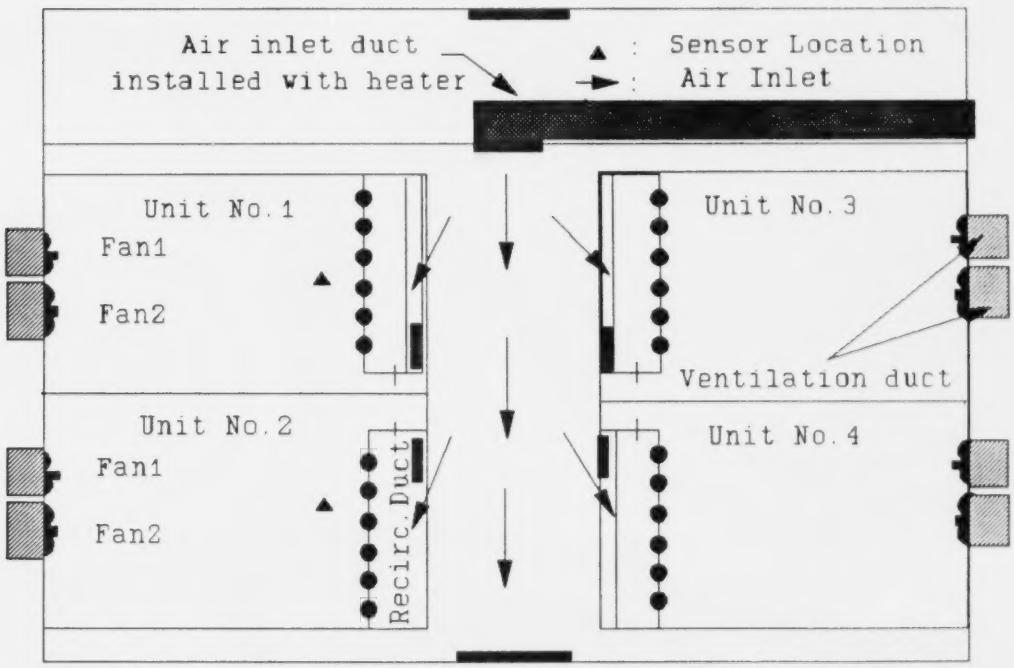

Figure 4 Layout of the experimental environment

Figure 4 shows the layout of the experimental units. Four individual testing units were each 3.4 x 4 x 2.4m in dimensions with a floor area of 13.6 m^2. A recirculation duct and counter-balanced continuous slot inlet ensured complete mixing of incoming air with the resident air. This

was ideally suited for this project since tests on control systems could be carried out under similar conditions. The two units (Unit No.1 and Unit No.2) chosen for the tests could be considered identical.

Unit No.1 was used for the sensor evaluation test. Eighty birds were housed in the unit during the broiler chicken trial and 75 birds were used for the turkey experiment. The control system evaluation was carried out in Units No.1 and No.2 with 75 turkeys in each unit.

Figure 5 shows a cross section elevation of the experimental units. The RH control system was operated for a period of 6 weeks in the two testing units. The air distribution patterns were considered the same for both units.

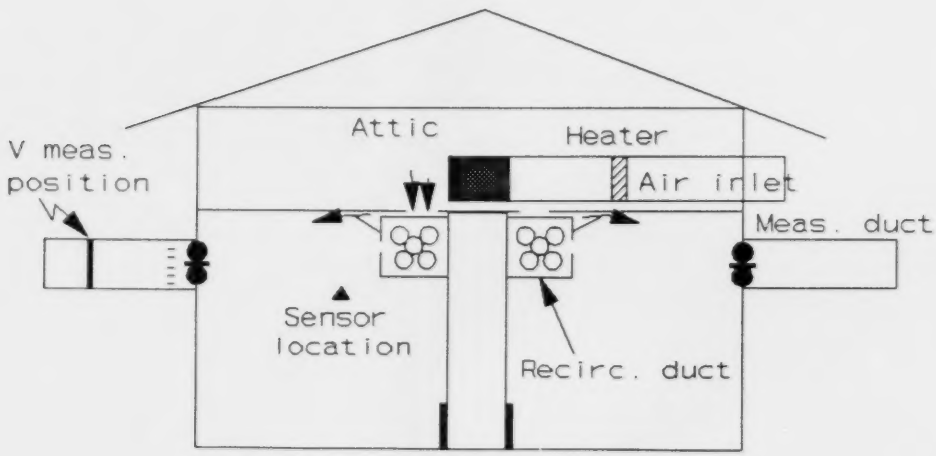

Figure 5 Cross section of the experimental units

During the sensor evaluation test, the air space temperature in the testing unit varied from 19.6 °C to 27.5 °C, and the relative humidity ranged from 14.8 %RH to 54.5 %RH under the broiler chicken conditions. In the turkey trial, the air space temperature ranged from 13.4 °C to 25.6 °C and the relative humidity ranged from 18.4 %RH to 63.2 %RH.

During the controller performance test, the air space temperature in the experimental units was nearly constant ranging from 25 to 27 °C. The inlet relative humidity levels in the attic were quite low and ranged from 12 %RH to 21 %RH.

This project was carried out in conjunction with a separate study of dust concentration. Canola oil was sprayed onto the litter for the turkey trial. The mean experimental values for dust and ammonia concentration are shown in Table 2 (Charles, 1990, Taschuk, et al.,1991).

Table 2 Dust and ammonia concentration in both trials

Parameter	Broiler trial	Turkey trial
Dust < 5micron (Particles/ml)	59.4	9.0
NH_3 (ppm)	12.1	12.9

As part of this different study, all fans were run at maximum speed for three days prior to activation of computer control. Two modified T731A Modufan controllers were used to separately control the environmental conditions in Unit No.1 and No.2.

4.5 Control System Modification

Because of the limited accuracy and reliability of commercial humidity sensors, direct control of humidity in animal environments is not common. The control strategies for minimum ventilation rate are usually based on temperature.

Maintaining a lower limit of ventilation rate for moisture control and introducing humidity as a control parameter would be desirable. A control system which allows both humidity and temperature control would be ideal.

A simple temperature-based controller was modified to provide a microcomputer-based humidity/temperature control system that would anticipate the interaction between temperature and relative humidity.

4.5.1 Operating principles of the temperature based controller.

Two modulating fan speed controllers (T731A Modufan, Honeywell, Scarborough, On.) were used for modification. The T731A Modufan is a modulating thermostat for control of

variable speed, permanent split capacitor (P.S.C) fan motors. The controller varies output voltage in proportion to temperature sensed within the air space. It varies the fan speed electronically using a line-voltage rated, high-speed electronic triac. The triac supplies a delayed phase-angle AC voltage to the controlled fan load. The phase angle delay varies in proportion to the sensed temperature.

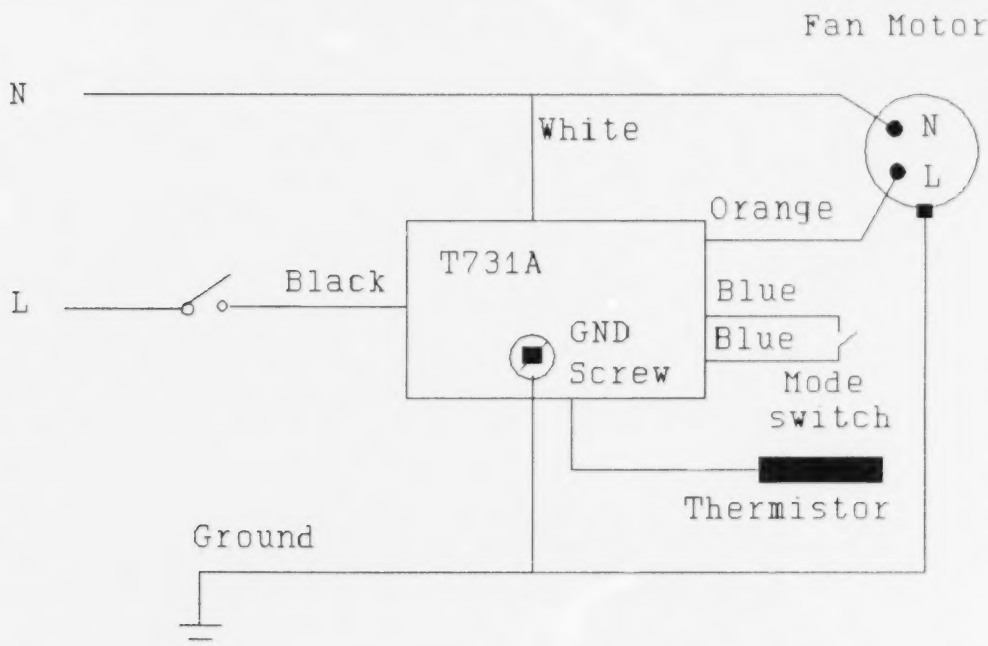

Figure 6 T731A Modufan controller
120 V Model connection diagram

Figure 6 shows the connection diagram of the T731A Modufan controller.

As sensed temperature increases, the RMS AC voltage supplied to the fan load increases, causing fan speed to increase. Similarly, as sensed temperature decreases, voltage supplied to the fan load will decrease.

The temperature sensor used in the controller is a thermistor. The leads of the thermistor are routed through a "covered" hole in the rear of the Modufan case and are permanently attached.

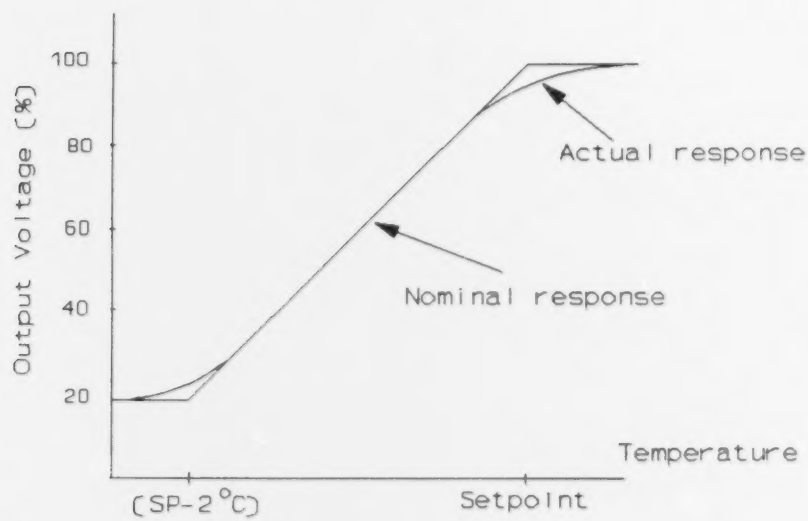

Figure 7 T731A Modufan controller
Characteristic curve (Fan-On mode)

Figure 7 presents the characteristic curve of the Modufan operation (fan-on mode). Under the fan-on mode, the

fan speed remains at a minimum rate, instead of stopping, at temperatures more than 2 °C below set point. Minimum output voltage is fixed, but actual fan speed and ventilation rate vary with the model and manufacturer of the ventilating fan and motor. The fan used for this project was a Model SD 12-EV variable speed fan manufactured by Canarm Ltd. (W. Brockville, ON.).

4.5.2 The Modification for computer-based control.

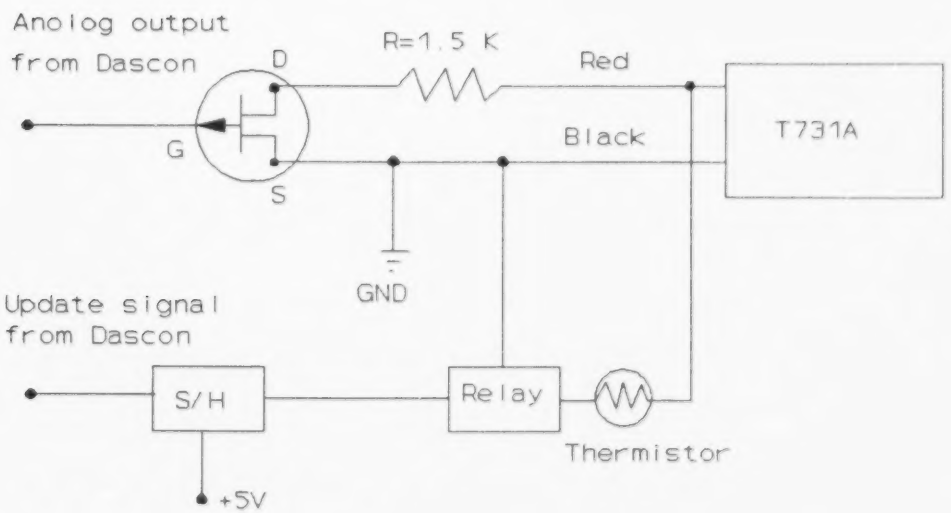

Figure 8 Thermistor simulation circuit

In order to control humidity levels in animal housing based on the RH signals, a relay switch was inserted between

the thermistor and the controller. This allowed the thermistor to be isolated from the controller. At the same time, a field effect transistor (FET) was placed in parallel with the thermistor as shown in Figure 8. The FET (2N5460) was used to simulate the thermistor when humidity-based control was required instead of temperature-based control.

Under temperature-based control, the resistance of the thermistor changed in response to temperature. Under humidity-based control, the current flow of the FET could be made to change by means of a computer-controlled analogue signal to the gate terminal that was dependent on measured RH.

4.6 The relative humidity control system

The relative humidity control system was a typical feedback control system as illustrated in Figure 9.

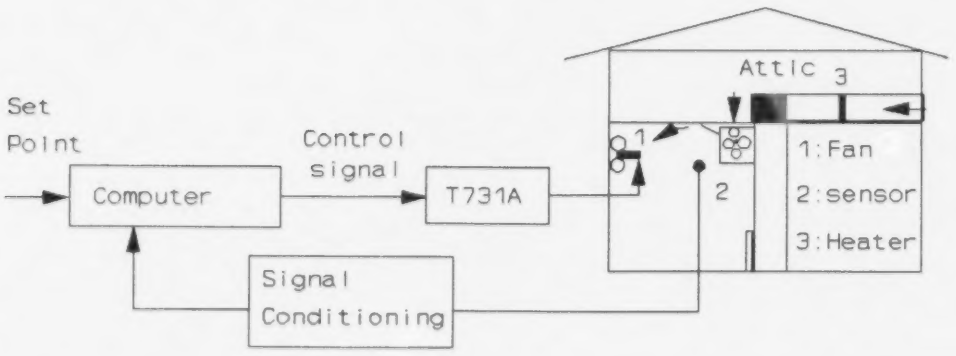

Figure 9 Feedback control system

The signals from the RH sensor, the temperature sensor, and the dew point hygrometer, were conditioned so that they were compatible with the rest of the system. The conditioned RH signal was compared with the RH set point. A voltage which was a function of the difference between the sensed signal and the set point was transmitted to the controller for control purposes.

Figure 10 shows the components of the micro-computer based control system.

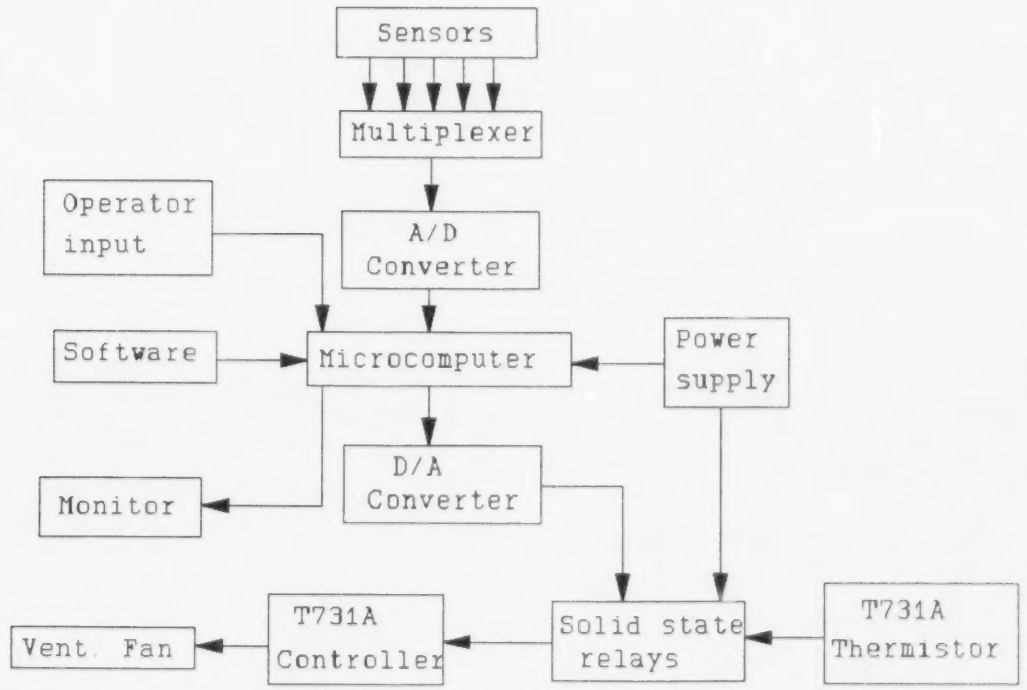

Figure 10 Components of the control system

As shown in Figure 10, the operation of the computer-

based system depended initially upon the sensors and signal conditioning circuitry.

The ambient temperature and the relative humidity inside the experimental units were measured by the RTD and the thin film polymer sensors respectively. The outside relative humidity was calculated from the dew point temperature measured by the dew point hygrometer. The output signals from both the RTD temperature sensor and the thin film polymer RH sensor ranged from 0 to 20 mA and were linear with respect to relative humidity and temperature.

4.6.1 Control signals from the D/A channel

The analog signals to the FETs were obtained from the two D/A output channels on the Dascon board. The signals were controlled according to the calibration of digital output against the ventilation rate. The ventilation rate was measured on the site, as described in section 5.1. The results (Appendix D) were used as a guide for determining the ventilation output for the control program.

4.6.2 Failure protection system

A failure protection system was required in this control system to maintain at least the minimum ventilation rate if ever a problem arose. The components in this circuit are shown in Figure 11.

The system was software-driven in that it was capable

of handling failures in the software. This protection was accomplished by updating the relay control signals every two seconds via a sample-and-hold (S/H) device (LF398). In the case of a software failure or a temporary power failure, the computer control system would be disconnected and the disabled thermistor switched back to the T731A controller. Under such a condition, the ventilation rate would change based on the response of the thermistor sensor and the original temperature set point for the T731A controller.

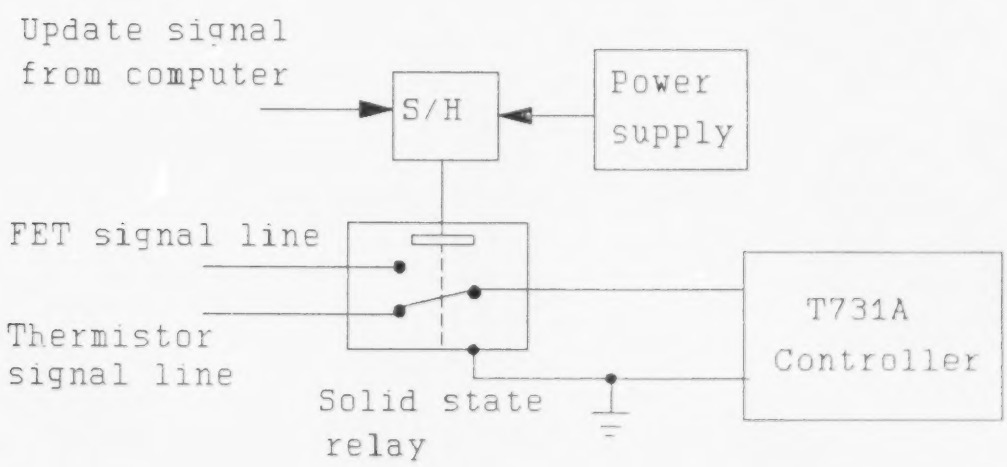

Figure 11 Failure protection circuit

4.6.3 Control Logic

A schematic diagram of the control logic is given in Figure 12. Inputs to the control logic were air temperature and relative humidity.

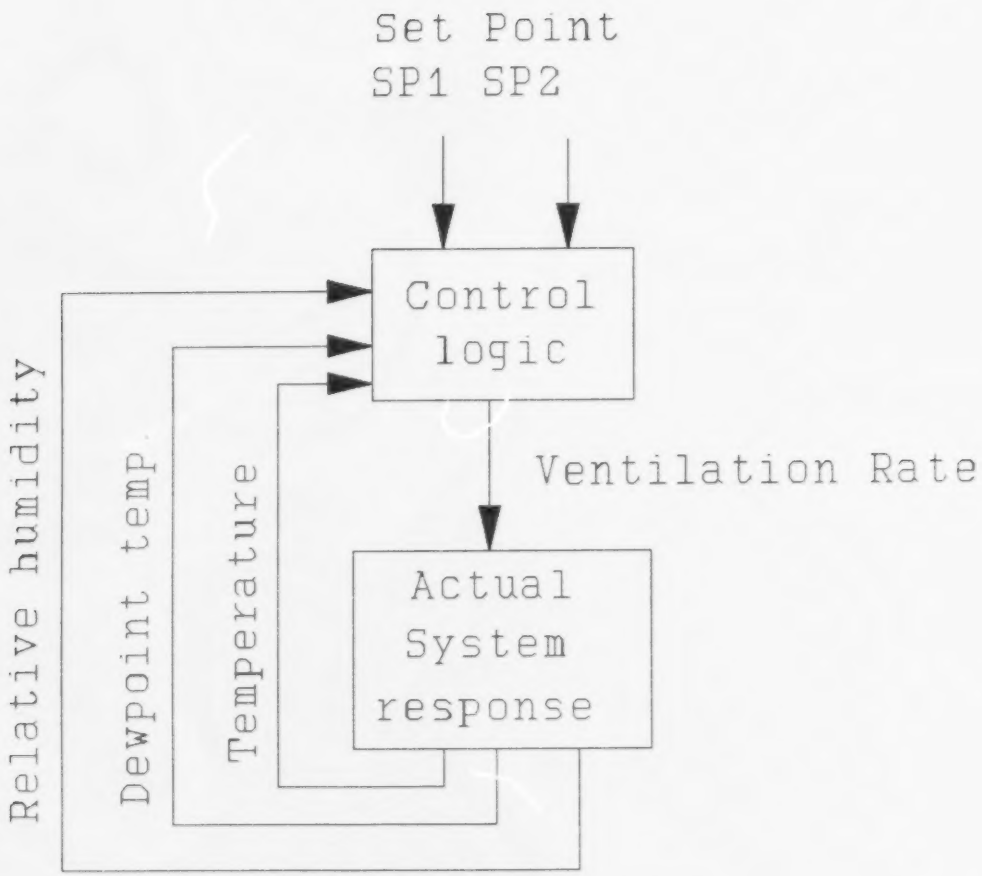

Figure 12 Control logic

The required ventilation rates were determined from the experimental set points. The ventilation rate increased or decreased according to the negative or positive offsets from the set point. If the relative humidity levels matched the set points to within ±2 %RH, the ventilation rate would

remain constant. The ventilation rate was changed by varying the signal from the FETs by means of the analog signals coming from D/A output channels in the Dascon board. Figure 13 illustrates this in the form of a flow chart. From the flow chart, some of the functions performed and the consideration given to the logic can be observed clearly.

The control program implemented on the IBM PC was written in BASIC language and the structure is illustrated in the flow chart given in Figure 13.

The time was entered at the beginning and, for controller evaluation, the controlling RH set points were changed automatically after the first 24 hours of operation. The relative humidity was calculated from the RH sensor input and was compared with the maximum and minimum allowable RH. A tolerance range of ± 2 %RH was selected for the control program. If the sensed RH was out of the allowable range, the ventilation rate would be changed by varying the D/A output signals.

Digital output to the D/A was changed in arbitrary increments of ± 100 as a first approximation for trials of the control system. It was anticipated that these increments could be changed in fine tuning of the control system. If the relative humidity exceeded the upper limits of the controlling set point range, a decreased D/A control signal was applied to the FET, and the ventilation rate would increase, and vice versa. The D/A increments were

simply numbers to control the FET working current, in themselves they had no physical significance but they were related to airflow rate as shown in Table 3.

4.6.4 Installation considerations

The power to the computer system was protected from power line disturbances by using a surge protector. This served to reduce induced noise experienced by the computer system due to the switching of other components, such as fans and heaters.

In order to provide a good sink for surge level voltages that might appear on the lines, a common ground was chosen for the system, it also served to reduce induced noise in the conductors. In addition, shielded cables were used to reduce the effects of electromagnetic fields on the signal lines.

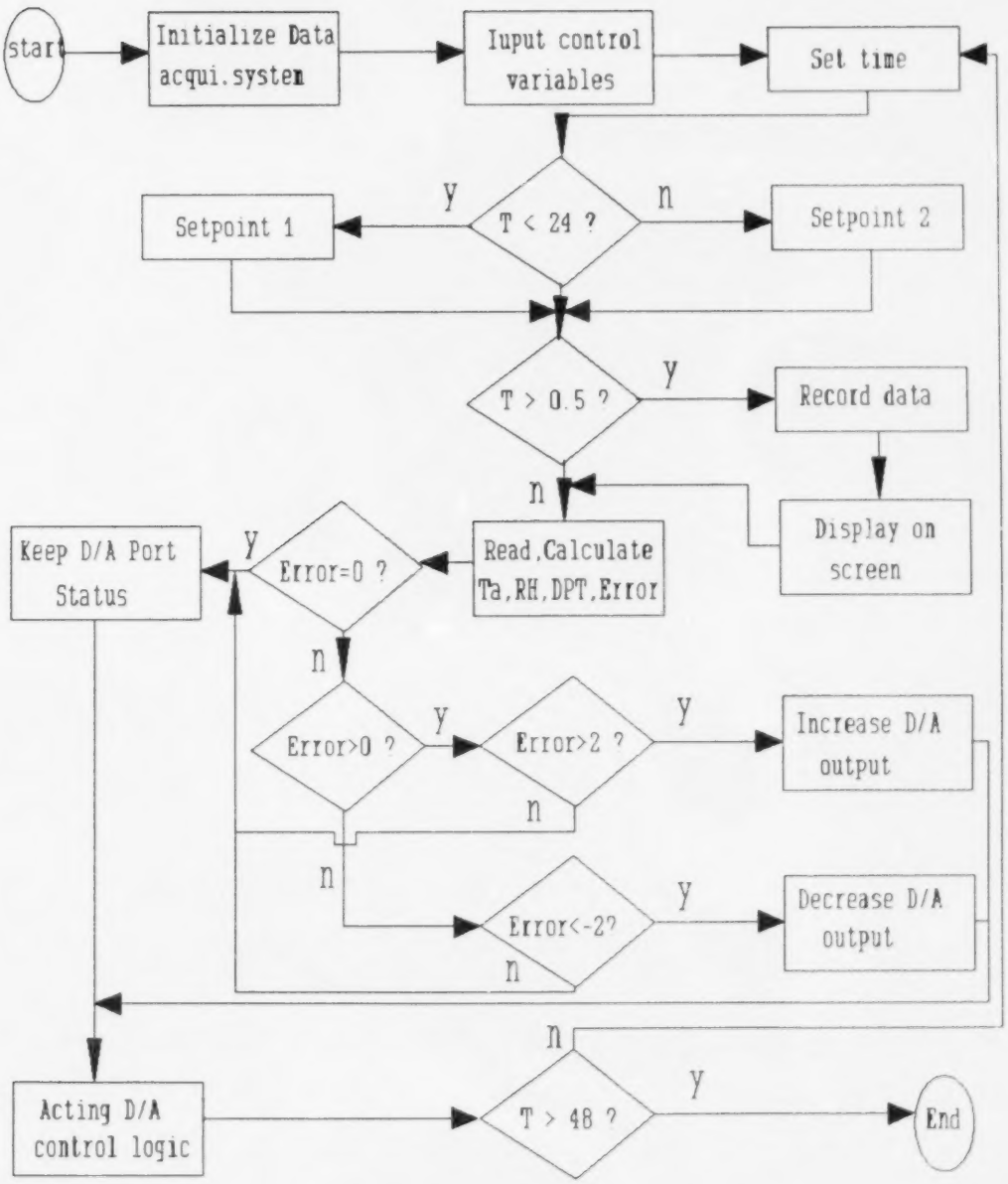

Figure 13 Flow Chart of Control Program

5. METHODOLOGY

5.1 Calibration

The two RTD temperature sensors and the two thin film RH sensors were calibrated prior to each test. The reference for the temperature was from a thermistor temperature sensor. The dew point temperature was obtained by the calibration of computer (A/D) reading against the displayed dew point temperature from the HYGRO-M1 sensor. The reference for relative humidity then was calculated from air temperature and dew point temperature. The data and regression equations for the sensors shown in Appendix A were obtained during this process.

Ventilation rate was calibrated against D/A output signals. For both modified RH controllers, higher digital outputs from the Dascon board to the D/A converter gave higher analog input to the simulated temperature sensor (FET). This caused the controlled fan to respond with a lower ventilation rate. On the other hand, a smaller digital output to the D/A converter provided a higher ventilation rate to the environment.

The air velocity flowing through the ducts was measured by an air velocity meter (Model 8350 Velocicalc, TSI Corp., St.Paul, MN.). The velocity meter had a range of 0.08 to 50.0 m/s, a reported resolution of 0.01 m/s and an accuracy of 2.5% of reading in the range of 0.15 to 2.5 m/s

(Anonymous, 1988). The time constant of the meter was set at 2 seconds for air velocity measurement.

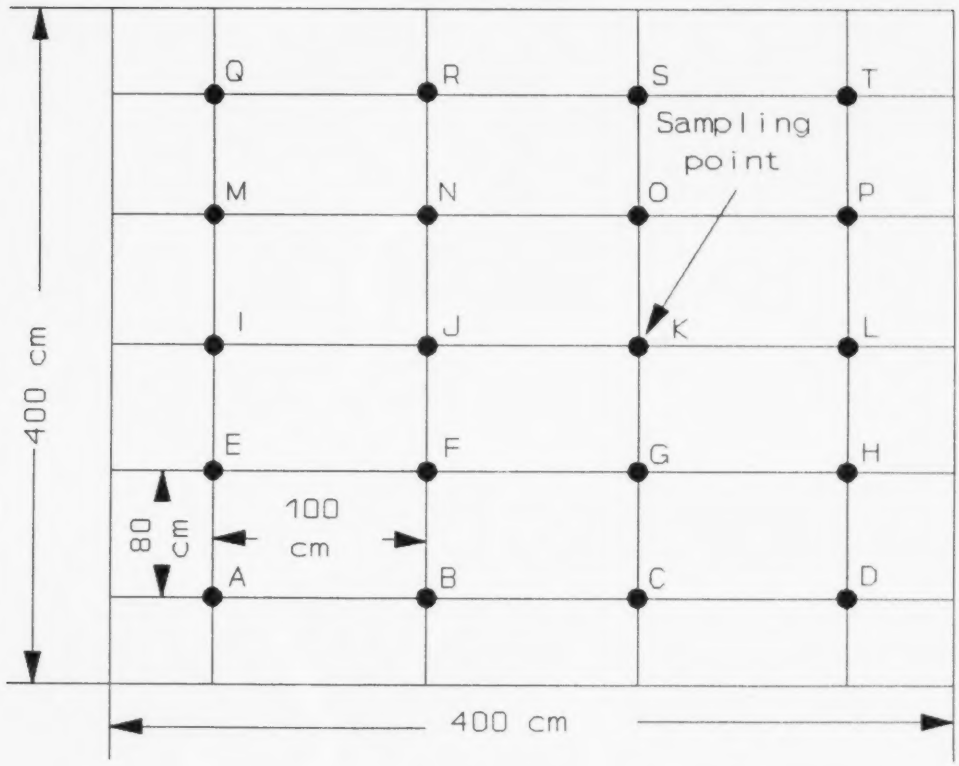

Figure 14 Sampling points along the cross section of the Duct

Figure 14 shows the location of the air velocity sampling points in the ventilation measuring duct. The velocity was measured at the location of 2.4m downstream of the measurement duct, and twenty sampling points were chosen for the calculation of the average velocity (Jorgensen,1983). At each sampling point, three measurements were taken and an average reading was recorded by using the AVERAGE function key on the meter.

5.2 Preliminary trials

Two preliminary trials were carried out. One prior to the sensor evaluation tests and one prior to the controller evaluation. In order to investigate the performance of thin film polymer sensors in a high relative humidity environment, a preliminary test of an RH sensor (HT-220) in a clean misted air space (Unit No.1) was conducted before the sensor evaluation test began. The humidity range generated from the misting system was from 64 to 100 %RH. The misting system was activated to gradually increase the RH in the airspace until an indication of 100 %RH was obtained. At that point the misting system was turned off and the RH was allowed to decrease. The sensor output and that from the reference dew point instrument were recorded at four-minute intervals for a total of 144 minutes. The objective of this trial was to verify the range over which the sensors could be tested.

A preliminary test to determine the required D/A output range was conducted prior to the control system performance evaluation. The variable analog signals were applied to the T731A controller through the disabled thermistor connections in the controller, and the output from the controller was recorded corresponding to certain analog input. As the operation of the controller was dependent on analog signals from the Dascon Board, the acceptable range of analog voltages had to be verified.

5.3 Sensor evaluation

The two sensors were tested against a reference relative humidity instrument to evaluate their performance over an extended period in animal housing conditions. The test was carried out first for seven weeks under broiler chicken conditions in spring, 1990, then for another seven weeks in a turkey environment during winter of 1990-91. Both sensors were cleaned and checked for proper operation before each test was conducted, and they were left in the testing units continuously once the test started. The two sensors were mounted side by side within the testing unit (Unit No.1), and the air sampling point for the reference was located at the same position with the two sensors. Measurements for all the sensors were recorded at ten minutes intervals once every week for a period of two consecutive days. The data were analyzed based on six-hour

intervals.

5.4 Control system evaluation

The performance of the RH-based controller was tested for accuracy as well as reliability over a period of six weeks in the turkey environment.

A Controller Performance Index (CPI) was defined in terms of %RH Error-Hour and was used to evaluate the performance of the controller. Thus, an error of 1 %RH for one hour would result in a CPI of one. Absolute values of error were used and these were measured at half-hourly which preliminary tests and the sensor evaluation had indicated would be adequate.

Two different humidity levels (30 %RH and 65 %RH) and two types of sensors (Model HT-220 and HT-46), as well as the 6-week exposure time to the animal environment, were considered as the main factors which could influence the performance of the modified controller. For the experimental design, these three factors: sensor type, relative humidity level and exposure time were chosen as the key factors for this cross factor experiment. Their influences on the performance of the controller were evaluated in terms of the Controller Performance Index (CPI).

The RH sensors were configured to allow them to be suspended from the ceiling of the controlled air space.

They were placed at the same position in each of the testing units, approximately 0.6 meters horizontally from the recirculation duct and 1.8 meters above the litter floor.

The set point for different humidity levels was automatically changed by the control program after 24 hours in operation. Data were recorded at 30 minute intervals for a total of two consecutive days every week for a 6-week period.

During the RH control period, the air space temperature and relative humidity in the experimental units as well as the relative humidity outside the units (RH in attic) were monitored. The analog signals to the FETs and the resulting ventilation rates were recorded simultaneously at 30 minute intervals.

In order to achieve the experimental plan, tests were conducted for a 24-hour period for each RH control set point. During this time, one room was maintained at high relative humidity and the other at the lower humidity level. At the end of the 24-hour period the control set points for each room were reversed and the test repeated for a further 24 hours. Based on the consideration that, during the set point changing period, there could be significant influence on the controller performance index, a two to four hour interval was allowed before data were used for statistical analysis.

The data were analyzed by using three-way, cross-

classification analysis of variance to test for the main effects from the three factors. A general linear model (Equation 5.1) was used for this purpose and the three-factor interaction term was considered as the valid error for the model:

$$Y_{ijk} = U + WK_i + RH_j + S_k + (WK*RH)_{ij} + (WK*S)_{ik} + (RH*S)_{jk} + E_{l(ijk)} \quad \ldots\ldots\ldots\ldots\ldots\ldots (5.1)$$

Where, Y_{ijk} = Predicted CPI

U = Population mean

WK_i = Effect of the ith week

RH_j = effect of the jth RH level

S_k = Effect of the kth sensor

$(WK*RH)_{ij}$ = Effect of interaction of Week i and RH level j

$(WK*S)_{ik}$ = Effect of interaction of week i and sensor k

$(RH*S)_{jk}$ = Effect of interaction of RH level j and sensor k

$E_{l(ijk)}$ = Random error within the (ijk) cell

6. RESULTS

6.1 Calibration

6.1.1 Sensors

Appendix A shows the results of the calibrations of sensor outputs against digital inputs to the data acquisition system. The calibration equations for the broiler trial are summarized as follows.

SENSOR HT-220:

Temperature (°C), $T1 = -34.487 + 0.018D_1$ $(R^2=0.99)$....(6.1)

RH (%), $RH1 = -28.792 + 0.033D_2$ $(R^2=0.99)$....(6.2)

SENSOR HT-46:

Temperature (°C), $T2 = -44.649 + 0.029D_3$ $(R^2=0.98)$....(6.3)

RH (%), $RH2 = -14.104 + 0.038D_4$ $(R^2=0.99)$....(6.4)

Dew point (°C), $DPT = -63.427 + 0.030D_5$ $(R^2=0.98)$....(6.5)

Similarly, the calibration equations for the turkey trial are shown below.

SENSOR HT-220:

Temperature (°C), $T1 = -36.061 + 0.019D_1$ $(R^2=0.99)$....(6.6)

RH (%), $RH1 = -23.599 + 0.029D_2$ $(R^2=0.99)$....(6.7)

SENSOR HT-46:

Temperature (°C), $T2 = -47.606 + 0.031D_3$ $(R^2=0.98)$....(6.8)

$$RH\ (\%),\ RH2 = -13.278 + 0.033D_4\ (R^2=0.99)....(6.9)$$

$$\text{Dew point } (^\circ C),\quad DPT = -64.866 + 0.031D_5\ (R^2=0.99)....(6.10)$$

Where, D_i = Digital reading from A/D input channel i

RH1 = RH reading from sensor HT-220

RH2 = RH reading from sensor HT-46

DPT = Dew point reading from the HYGRO-M1 sensor

6.1.2 Air flow

The results of the calibration of air flow against digital output to the controller were tabulated in Appendix D. A summary of results is provided in Table 2 which illustrates the relationship between air flow in the ducts and the digital output to the D/A converter.

Table 3 Air flow rate and computer digital output

DUCT #1		DUCT #2	
Digital output	Q (m^3/s)	Digital output	Q (m^3/s)
0	0.55	0	0.52
400	0.54	400	0.50
600	0.48	600	0.48
800	0.40	800	0.35
1000	0.09	1000	0.09
1200	0.08	1200	0.08
1600	0.07	1600	0.08
2000	0.07	2000	0.07

The calibration equations derived from Table 4 are as follows:

Duct #1.

$$Q = 0.5638 + 2.348*10^{-4}*D_1 - 9.303*10^{-7}*D_1^2 + 3.0*10^{-10}*D_1^3 \quad (R^2=0.91) \ldots\ldots (6.11)$$

Duct #2.

$$Q = 0.5341 + 1.967*10^{-4}*D_2 - 8.412*10^{-7}*D_2^2 + 3.0*10^{-10}*D_2^3 \quad (R^2=0.91) \ldots\ldots (6.12)$$

Where,

Q = Average flow rate in the ventilation duct (m^3/s)

D_1 = Computer digital output to controller #1

D_2 = Computer digital output to controller #2

6.2 Preliminary trial

The results of HT-220 sensor's performance compared with the reference source over a range of 64 %RH to 95 %RH is presented in Figure 15 and Appendix B.

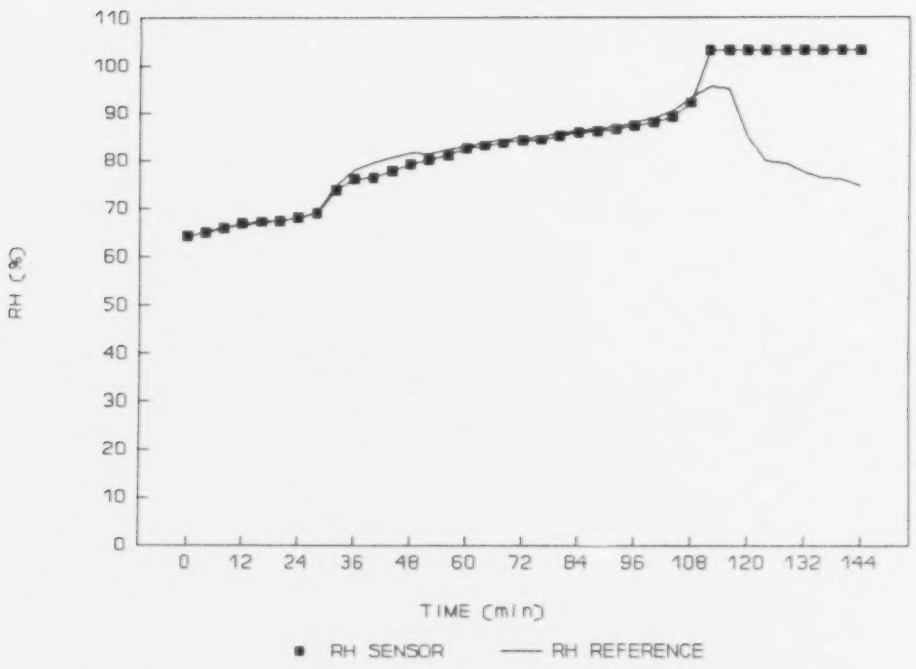

Figure 15 Performance of RH sensor in a misted air space

The result of the controller's characteristics test is shown in Table 4.

Table 4 Controller Voltage tests

Set point (°C)	Controller T731A	Vdc for low Vac output (V)	Vdc for high Vac output (V)	Vdc range (V)
0	CTL #1	9.72	8.88	0.84
	CTL #2	9.41	8.53	0.88
10	CTL #1	8.32	7.44	0.88
	CTL #2	8.01	7.12	0.89
20	CTL #1	5.83	5.01	0.82
	CTL #2	5.61	4.77	0.84
30	CTL #1	3.27	2.34	0.93
	CTL #2	3.01	2.03	0.98
35	CTL #1	2.04	0.43	1.61
	CTL #2	1.75	0.13	1.62

6.3 Sensor evaluation

Table 5 shows the comparison of the temperature measurements taken with the two Pt100 RTD sensors. Under the conditions of broiler chicken and turkey environments, only minor differences were noted between the two sensors. The temperature calibrations of the two sensors were both against a previously-calibrated thermistor reading. Since the aim was not to evaluate the performance of the RTD temperature sensors, the signals from only one of the RTD

sensors were used as the temperature reference. This eliminated the effects of different temperature readings on the reference relative humidity calculations. Nevertheless, the agreement of the two temperature sensors was monitored throughout the experiments. The results show that the largest average mean difference for a two-day sampling period was 0.8 °C between the two RTD sensors.

Table 5 Comparison of the two RTD readings

Week	Temp. 1 (°C)	Temp. 2 (°C)	Difference (°C)
2	24.3	24.8	0.5
3	25.0	25.3	0.3
4	24.8	25.4	0.6
5	23.4	23.8	0.4
6	23.9	24.4	0.5
7	24.8	25.6	0.8

The comparisons of the relative humidity measurements taken with the two sensors and the reference source are given in Figures 16 and Figure 17.

To help interpret the results, differences were calculated between the relative humidity measurements made with each RH sensor and the measurements made at the same time with the reference source. The means of the absolute value of these differences are given in Table 6.

Table 6 Comparison of the two RH sensors with the reference source

	HT-220	HT-64
Broiler Barn		
No. of observations	56	48
Means of differences (± Std. Error)	1.14±0.12	1.61±0.14
Minimum difference	0.03	0.04
Maximum difference	3.99	4.42
Quartiles (Q3-Q1)	1.39	1.52
Turkey Barn		
No. of observations	56	56
Means of differences (± Std. Error)	1.66±0.16	1.90±0.16
Minimum difference	0.06	0.01
Maximum difference	4.38	5.63
Quartiles (Q3-Q1)	2.15	2.0

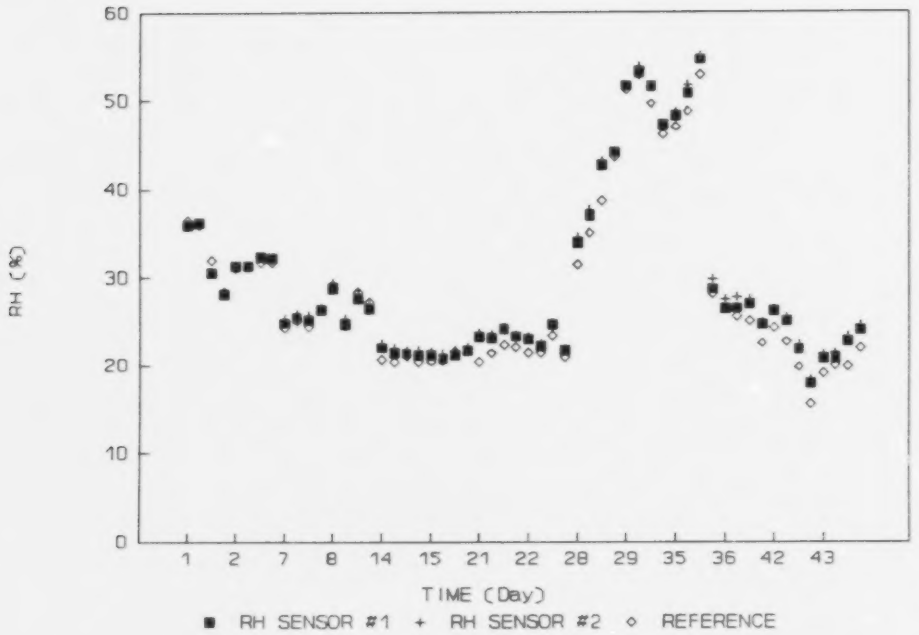

Figure 16 Comparison of the two RH sensors with reference source in broiler chicken environments

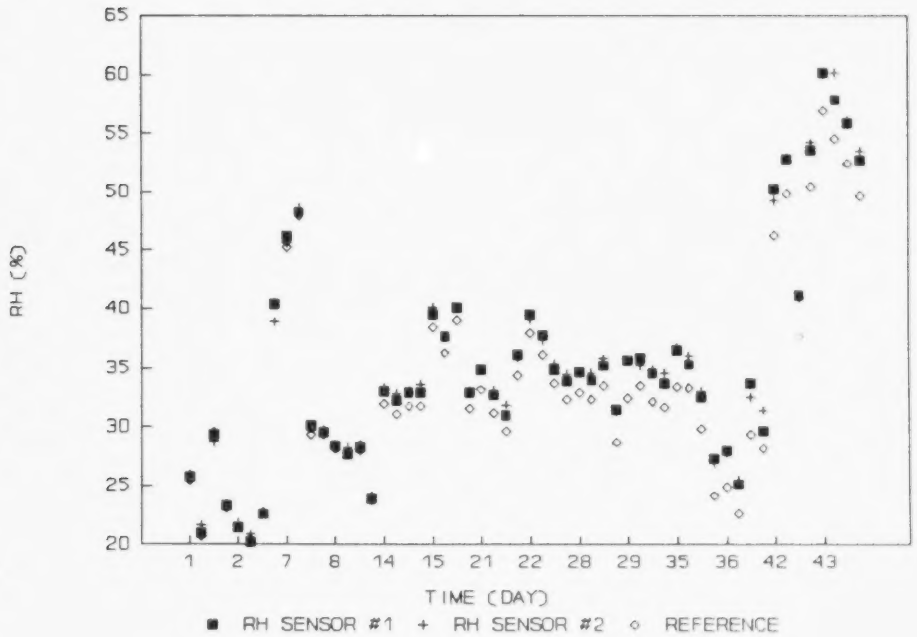

Figure 17 Comparison of the two RH sensors with the reference source in turkey environments

The mean differences at one-week intervals were calculated and are shown in Table 7. The relationship between the exposure time and the accumulated drift were established by the regression equations 6.13 to 6.16.

Table 7 Relationship between the sensors exposure time and the accumulated offset

Sensors in broiler trial			Sensors in turkey trial		
Week	HT-220	HT-46	Week	HT-220	HT-46
1	-0.03	-	1	0.01	0.02
2	-0.02	0.48	2	0.35	0.45
3	0.46	0.93	3	1.19	1.47
4	1.49	1.73	4	1.56	1.72
5	1.60	1.87	5	2.22	2.44
6	1.34	2.08	6	2.79	3.00
7	2.00	2.45	7	3.30	3.64

Under broiler chicken environments

$$\text{HT-220: } RH_{Drift} = -0.444 + 0.355W \quad (R^2=0.86) \quad .....(6.13)$$

$$\text{HT-46 : } RH_{Drift} = 0.246 + 0.384W \quad (R^2=0.94) \quad .....(6.14)$$

Under turkey environments

$$\text{HT-220: } RH_{Drift} = -0.623 + 0.564W \quad (R^2=0.99) \quad .....(6.15)$$

$$\text{HT-46 : } RH_{Drift} = -0.599 + 0.605W \quad (R^2=0.99) \quad .....(6.16)$$

Where,

W = Week

RH_{Drift} = Output drift from the sensor (%)

6.4 Control system evaluation

The performance of the RH control system during the six-week experiment are presented in graphical form in Figures 18 to 29. The RH set points were 30 %RH and 65 %RH for low and high RH control respectively.

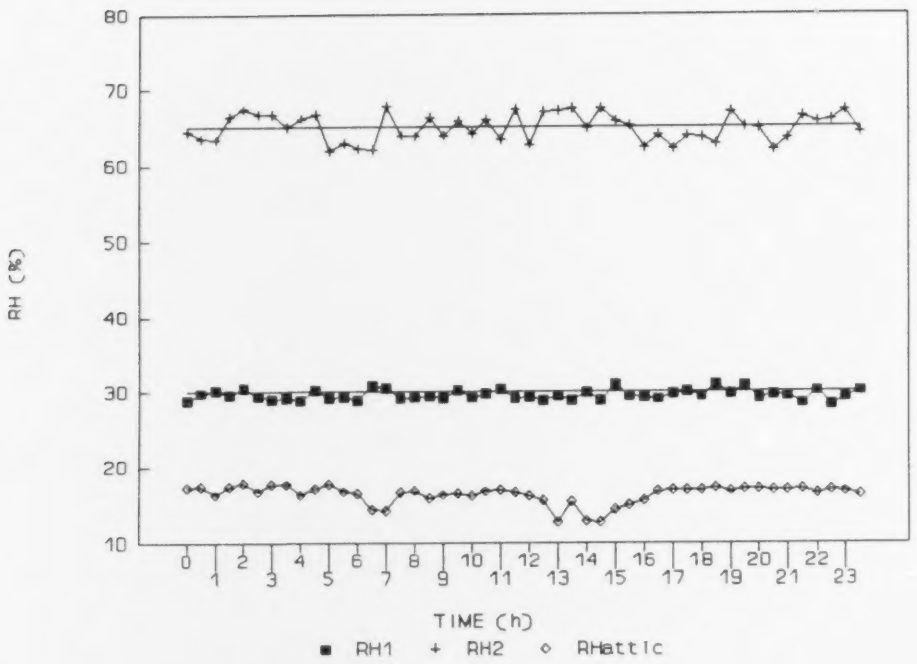

Figure 18 Graph of RH in the controlled spaces and attic during day 1 week 1

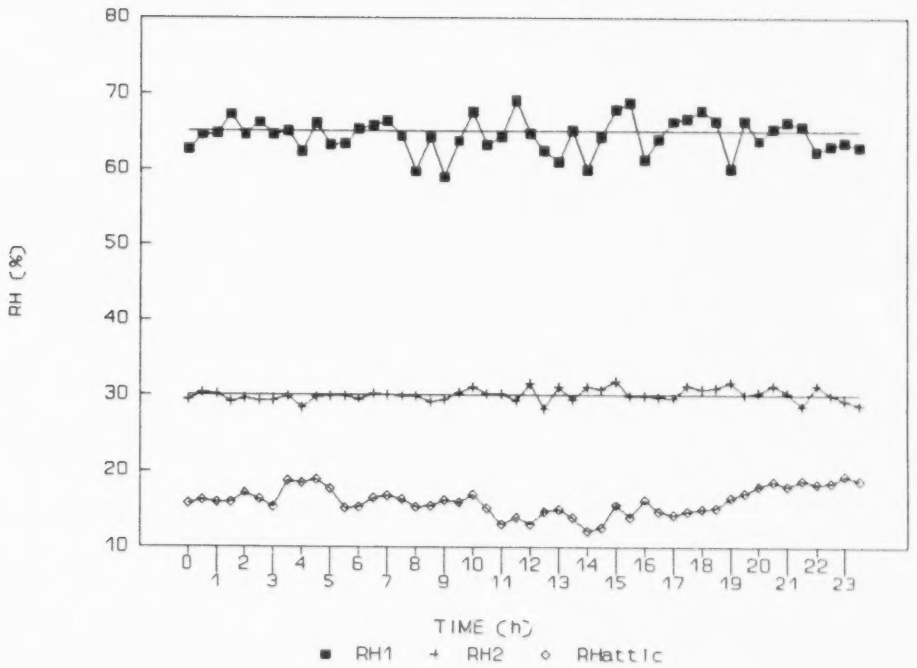

Figure 19 Graph of RH in the controlled spaces and attic during day 2 week 1

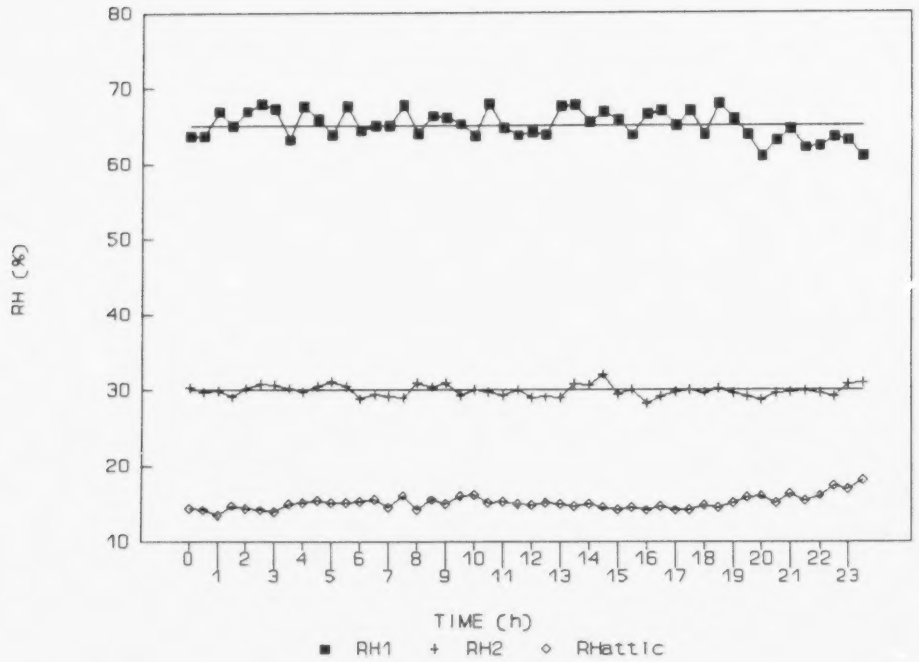

Figure 20 Graph of RH in the controlled spaces and attic during day 1 week 2

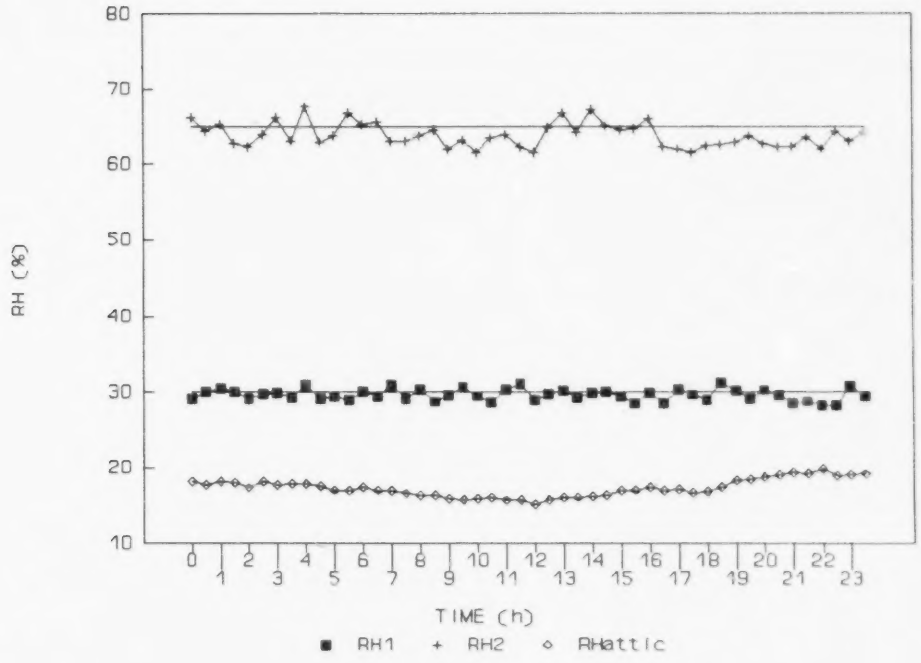

Figure 21 Graph of RH in the controlled spaces and attic during day 2 week 2

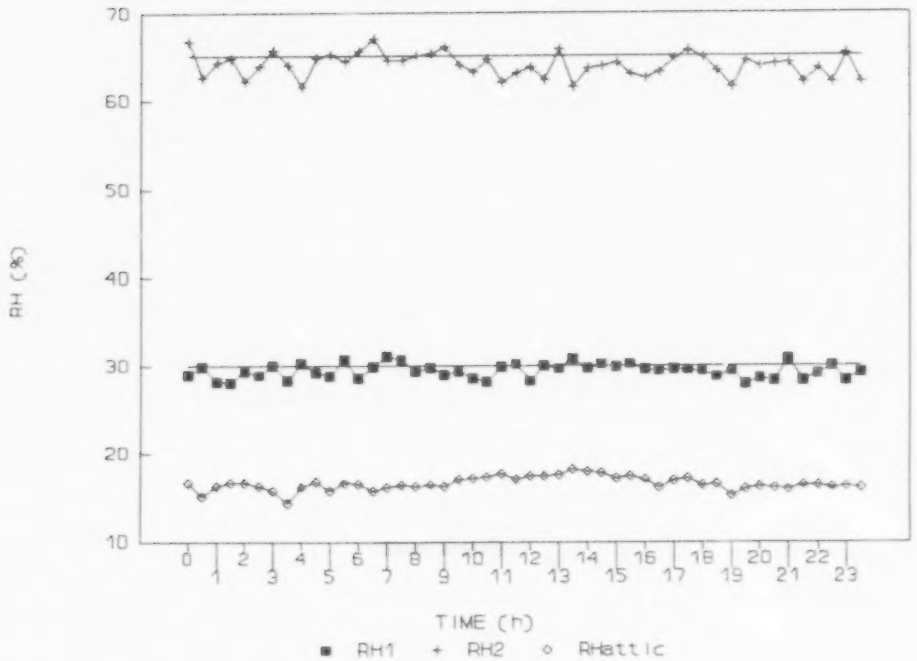

Figure 22 Graph of RH in the controlled spaces and attic during day 1 week 3

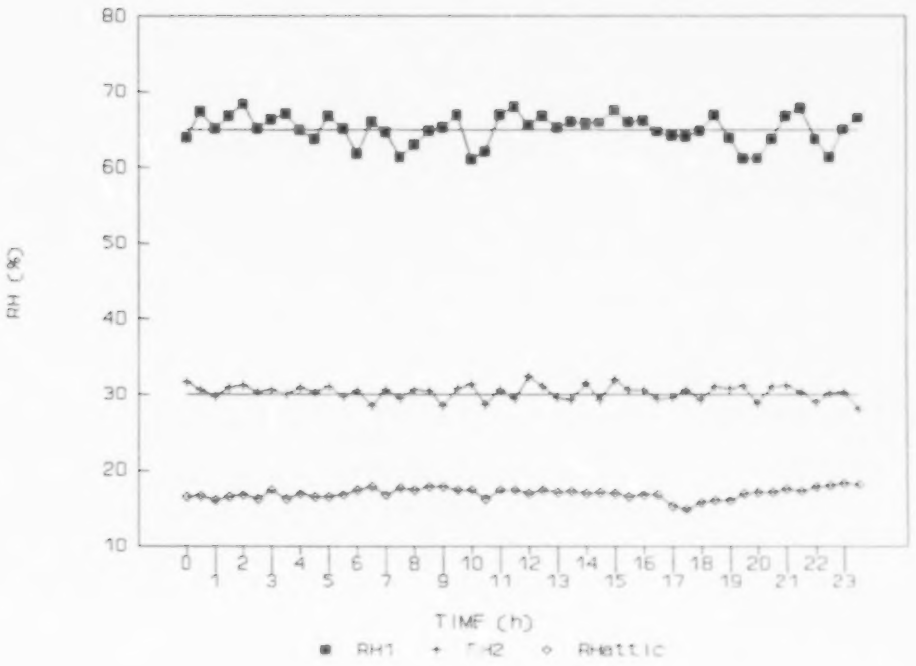

Figure 23 Graph of RH in the controlled spaces and attic during day 2 week 3

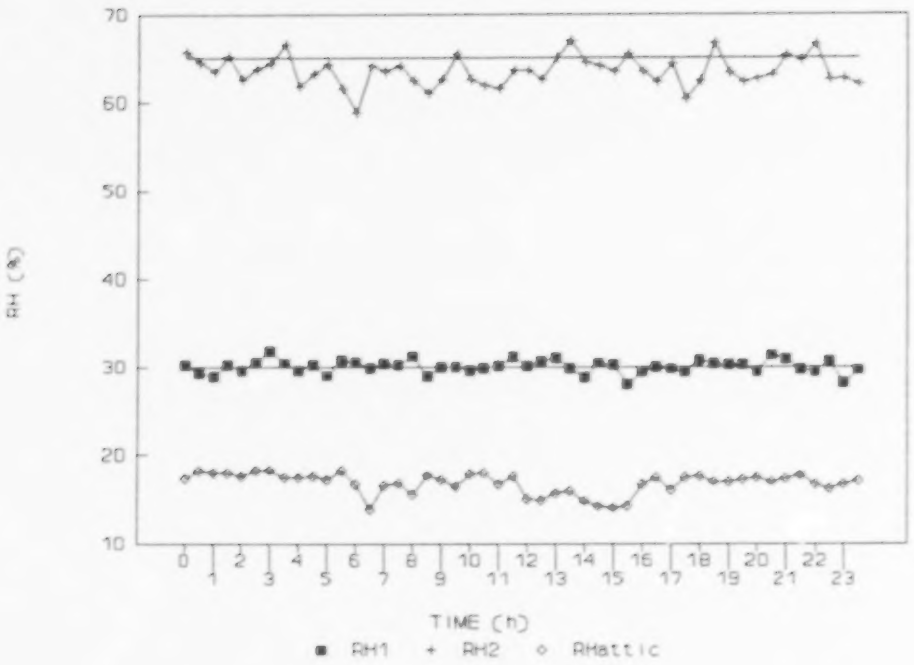

Figure 24 Graph of RH in the controlled spaces and attic during day 1 week 4

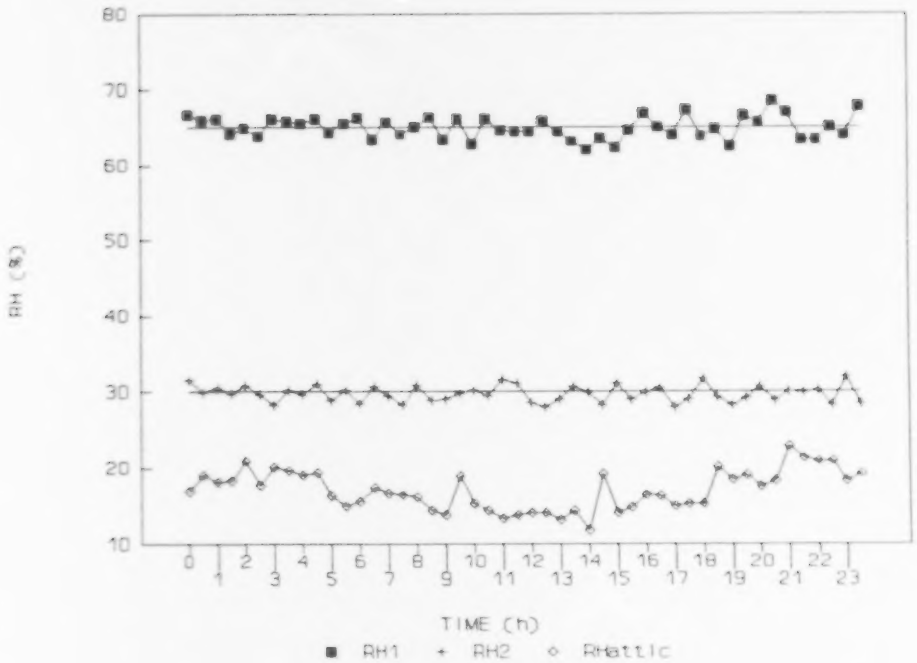

Figure 25 Graph of RH in the controlled spaces and attic during day 2 week 4

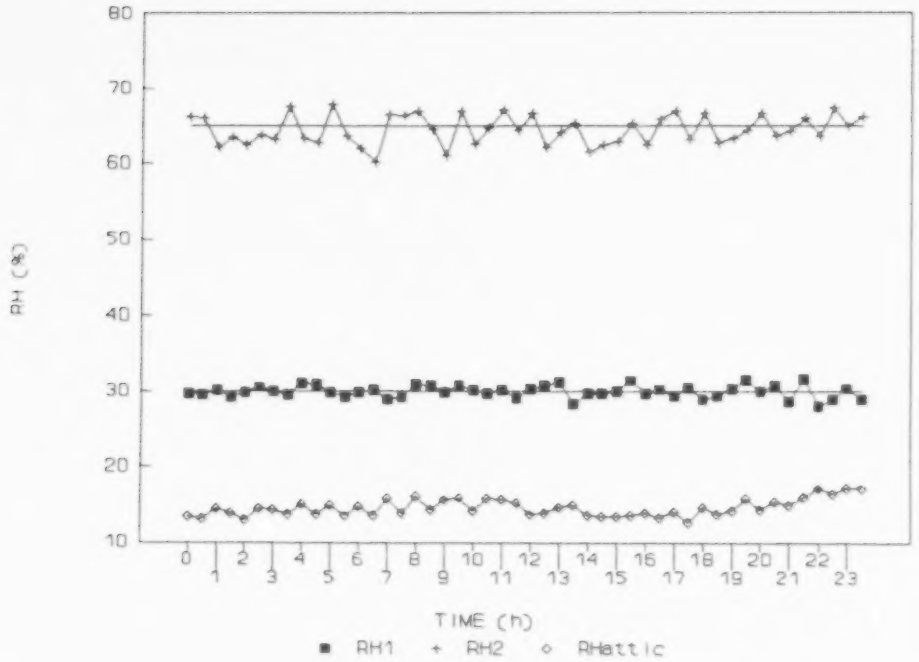

Figure 26 Graph of RH in the controlled spaces and attic during day 1 week 5

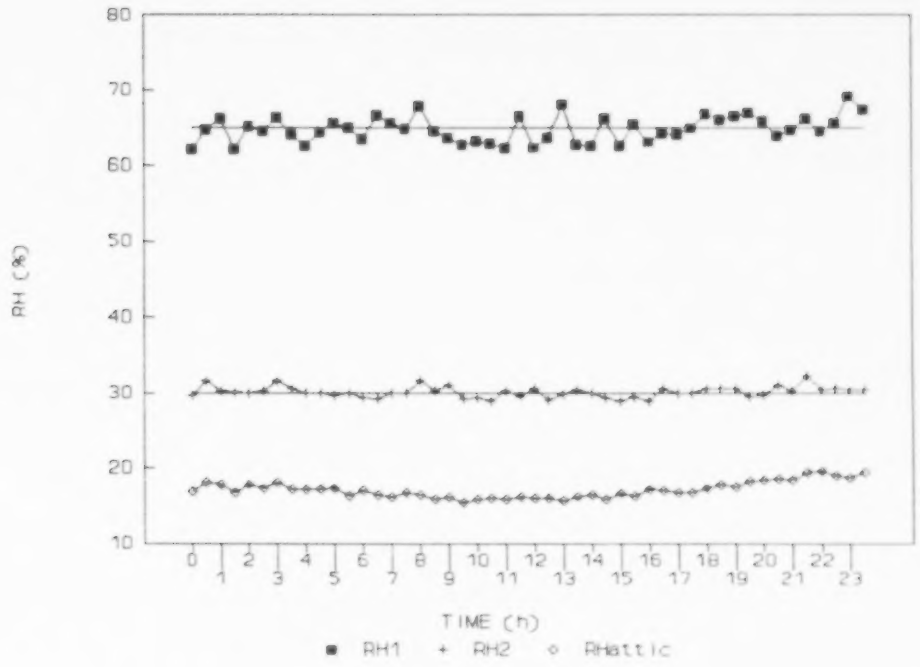

Figure 27 Graph of RH in the controlled spaces and attic during day 2 week 5

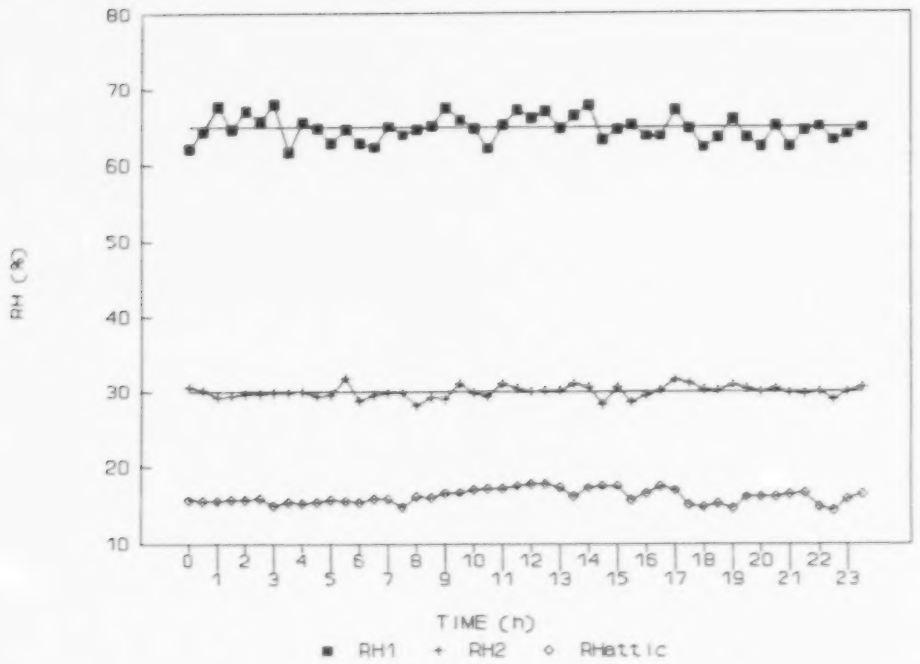

Figure 28 Graph of RH in the controlled spaces and attic during day 1 week 6

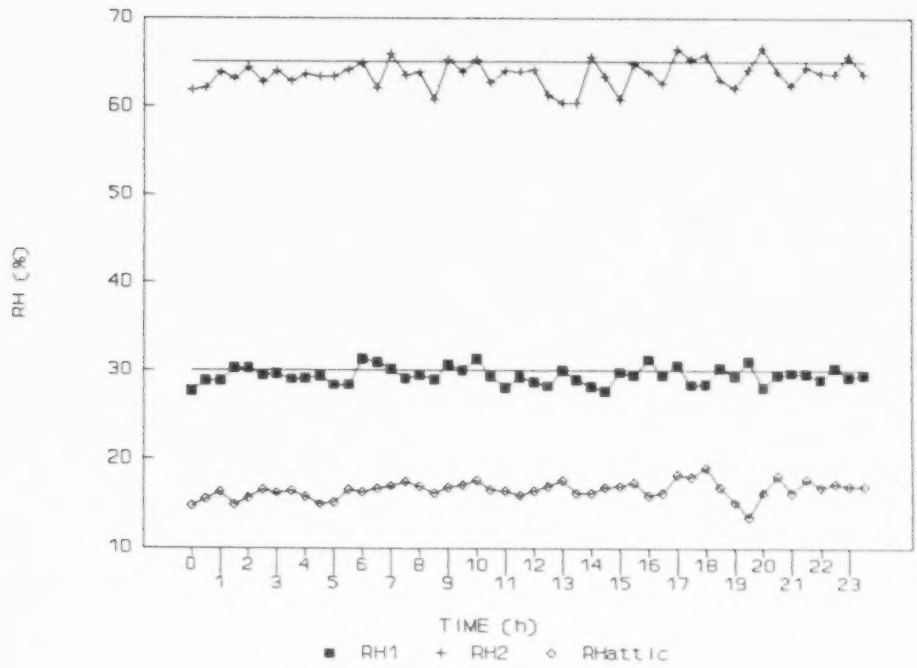

Figure 29 Graph of RH in the controlled spaces and attic during day 2 week 6

The results presented in Figure 18 to 29 provide a qualitative picture of the control system performance. In order to determine the significance of any differences in performance due to sensors, RH levels and time, an analysis of variance was carried out using the general linear model in SAS on the University of Alberta's VM computer system. The probability level of less than 0.05 was considered significant for this test. The results of the analysis are presented in Table 8 while Table 9 gives the mean CPI values together with standard deviations.

Table 8 General linear model analysis of variance

SOURCE	DF	SS	MS	F VALUE	$P_r > F$
WK	5	0.882	0.176	0.25	0.941
LEVEL	1	209.441	209.441	294.31	0.0001**
SENSOR	1	0.829	0.829	1.16	0.281
WK*LEVEL	5	7.231	1.446	2.03	0.072
WK*SENSOR	5	12.481	2.496	3.51	0.004
LEVEL*SENSOR	1	2.109	2.109	2.96	0.085
WK*LEVEL*SENSOR	5	8.118	1.624	2.28	0.045

** The effect of relative humidity levels on CPI was highly significant ($P < 0.01$).

Table 9 Some results from the General Linear Model

Observed Data		
SOURCE	MEAN (CPI)	SD
High RH level	1.57	1.07
Low RH level	0.72	0.53
Sensor #1	1.12	0.95
Sensor #2	1.17	0.96
Week 1	1.19	1.05
Week 2	1.15	0.91
Week 3	1.16	0.92
Week 4	1.14	0.95
Week 5	1.10	0.92
Week 6	1.13	0.96

7. DISCUSSION

7.1 Calibration

The calibration equations (equation 6.1 to 6.10) of the sensors indicated that the two thin film polymer sensors (Model HT-220 and HT-46) had an excellent linearity between their generated current output and relative humidity (R^2=0.98 to 0.99).

7.2 Preliminary trials

7.2.1 Sensor

The performance of HT-200 sensor was illustrated in Figure 15. This Figure indicated that the readings from the RH sensor followed the reference source very closely in the range of 64 to 95 %RH. However, the sensor failed to give correct readings when the air space humidity level was over 95 %RH. Even when the air space humidity level was reduced, the sensor still did not recover quickly from the saturated condition.

Condensation was observed on the sensor probe in this test and it was concluded that, for the sensor to provide accurate results, the air space humidity level should be Kept below 95 %RH. These results are in contrast to those of Ross et al. (1988) who observed that a sensor from the same manufacturer recovered rapidly from exposure to condensed moisture.

7.2.2 Controller voltages

The results in Table 4 demonstrated that when the average (V_{ac}) voltage supplied to the fan load changed from the lowest value (approx. 20 V_{avg}) to the highest value (approx. 98 V_{avg}), the largest control (V_{dc}) ranges required for both controllers were around 1.6 volts. For control purposes, a large analog signal input range was desired in order to provide greater control sensitivity.

From the preliminary investigation, it was found that the largest analog input range occurred at the temperature set point of 35 °C. At this temperature set point, the controller also made it possible for the fan speed to remain at the minimum value when the original thermistor sensor was switched back into operation. Therefore, the temperature set point was set at 35 °C for both controllers under the field test.

7.3 Sensor evaluation

The data from the broiler chicken trial indicated that the sensors performed slightly better than under the turkey environments, with mean differences of 1.14 %RH and 1.61 %RH for HT-220 and HT-46 respectively compared with 1.66 %RH and 1.9 %RH for the two sensors in the turkey trial.

Both of the sensors performed well with the maximum mean observed difference between sensor and reference reading being 3.6 %RH. High readings relative to the

reference source were consistently observed over the course of the experiment. There was a linear relationship between the sensor's signal shift and time. This could have been due to the sensors' prolonged exposure to ammonia and the accumulation of dust on the filters. However, as can be seen from Table 2, the drift did not appear to be related to dust concentration and the ammonia concentrations were not high in either trial. Further tests would be required to establish whether this drift was repeatable and, if so, what was causing it. These results are also in contrast to those of Ross et al. (1988) who observed that a sensor from the same manufacturer had readings consistently below a reference instrument.

In the turkey trial, the signal drift was slightly greater than those in broiler trial. The precise reason for this is unclear, but as the sensors had been used already for the broiler trial, it is possible that the increased drift was due to the sensor age. In addition, the turkey litter having been oiled with canola oil might have had some unmeasured effect on aerial contaminants that, in turn, could have influenced the sensor's performance.

As the two sensors were calibrated prior to each test, the accuracy of the sensors could be judged on the basis of the variability, over the test period, in the deviations between the sensor readings and the reference instrument reading. Equations of 6.13 to 6.16 could be used as a guide

to approximate corrections in similar environments.

The signal shifting ranges between the two trials appeared not to have a marked difference, this could be explained by assuming that the dust concentrations did not have key effects on the performance of the sensors.

7.4 Controller performance

As indicated in Table 8, the sensor types and exposure time had no significant effects on the performance of the controller. The effect of relative humidity levels were highly significant.

For the high RH set point, a mean CPI of 3.14 with a standard deviation of 1.07 was observed. The results for the low RH set point show a 54% decrease in CPI with a standard deviation of 0.53.

Control of RH around the set points was accomplished very well, but there was a larger fluctuation of RH around the high control set point than the low set point. The reason for this was because of the low relative humidity levels in the attic. For the low RH set point, the fan was run most of the time at its maximum ventilation rate and the control performance was assisted by the low attic relative humidity levels. However, for the high RH set point, the increase of moisture in the air space was achieved by lowering ventilation rate and, at the same time, keeping the moisture generated from the birds as high as possible.

As the misting system was not used for RH control, once the relative humidity level reached the high set point, the ventilation rate began increasing accordingly. In the case of over-ventilation or when relative humidity levels became lower than the RH set point, it took a certain time to raise the humidity levels by means of moisture generation from the birds and litter. This process cannot be controlled effectively by the simple control program used in this experiment.

The data in Table 8 and Table 9 indicate that the simulated temperature sensor and the modified control system can effectively control humidity by varying the ventilation rate. But, as mentioned earlier, low rate of moisture production by birds and litter gave slow response, and correspondingly poorer control, at a high set point. If the attic air had been more humid this problem would not have been as obvious.

Nevertheless, with the help of this control system, it is possible to select different control strategies such as temperature control, relative humidity control, or temperature and humidity combination control. The control system could create selected humidity levels in animal environments, and different control strategies as well as the influence of humidity on the air quality in livestock buildings could be investigated under such an environment.

8. SUMMARY AND CONCLUSIONS

Based on the results obtained in this study, the following conclusions were drawn.

1. Besides the drift (less than 3.6 %RH) during the 7-week test period, the accuracy and the stability of the two thin film polymer relative humidity sensors (HT-220 and HT-46) in both broiler chicken and turkey environments were comparable to the reference instrument. The drift of the sensors relative to the reference RH could be approximated by using the regression equations developed earlier as a guide, namely,

Under broiler chicken environments

HT-220: RH_{Drift} (%) = -0.444 + 0.355W

HT-46 : RH_{Drift} (%) = 0.246 + 0.384W

Under turkey environments

HT-220: RH_{Drift} (%) = -0.623 + 0.564W

HT-46 : RH_{Drift} (%) = -0.599 + 0.605W

2. The effects of the environment appeared not to have a marked influence on the sensors' performance. Dust concentration was not proportional to signal drift. In both trials, the signal drifts could be due to the sensors prolonged exposure to ammonia although the levels were not

high (in both cases, the average ammonia concentration was about 12 ppm) and the dust accumulation on the filters.

3. The slightly higher signal drift in turkey trial could have been due to the sensors' age and some unmeasured effect on aerial contaminants caused by the application of canola oil to the litter.

4. The modified computer-based control system performed well at the two relative humidity set points. The system performed better at the low RH set point than at the high RH setpoint with a CPI of 1.44 for low RH and 3.14 for high RH.

5. The effects of sensor type and exposure time on the performance of the controller were statistically insignificant.

6. Because the evaluation of the control system was based on two similar sensors from one manufacturer, the results are limited in their general applicability.

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APPENDIX A

THE CALIBRATION FOR HT-220, HT-46 AND HYGRO-M1 SENSORS

APPENDIX A1. CALIBRATION FOR HT-220 PRIOR TO BROILER CHICKEN TRIAL

CAL1 FOR SENSOR #1 (TEMP)		CAL1 FOR SENSOR #1 (RH)	
TEMP (°C)	A/D	A/D	RH (%)
17.48	2862	1945	33.7
17.88	2870	1963	34.6
18	2882	2028	36.8
18.49	2912	2040	37.8
19.07	2958	2060	38.9
19.49	2979	2100	39.9
20.06	3008	2152	41.8
20.46	3026	2233	43.8
21	3058	2325	45.6
21.65	3099	2331	47.1
22.03	3126	2353	48.2
22.91	3170	2398	49.3
23.36	3192	2417	50.5
23.87	3221	2493	52.5
24.14	3219	2538	53.4
24.61	3257	2583	54.6
25.1	3283	2589	55.5
25.65	3307	2640	57.2
26.1	3323	2675	58
26.27	3340	2703	59.1

Regression Output (TEMP):

Constant	-34.4871
Std Err of Y Est	0.147533
R Squared	0.997598
No. of Observations	20
Degrees of Freedom	18
X Coefficient(s)	0.018156
Std Err of Coef.	0.000209

Regression Output (RH):

Constant	-28.7916
Std Err of Y Est	0.515982
R Squared	0.996214
No. of Observations	20
Degrees of Freedom	18
X Coefficient(s)	0.032686
X Coefficient(s)	0.032515
Std Err of Coef.	0.000472

APPENDIX A2. CALIBRATION FOR HT-46 PRIOR TO BROILER CHICKEN TRIAL

CAL1 FOR SENSOR#2 (TEMP)		CAL1 FOR SENSOR#2 (RH)	
A/D	TEMP (°C)	A/D	RH (%)
2133	19.33	848	18.3
2147	19.45	858	18.96
2186	20.02	869	19.04
2193	20.4	877	19.2
2207	20.82	889	19.47
2198	20.99	893	19.88
2232	21.2	910	20.25
2229	21.46	918	20.76
2245	21.89	932	21.44
2267	22.23	941	21.69
2250	22.5	950	22.03
2269	22.93	957	22.41
2268	23.14	963	22.76
2310	23.64	979	23.21
2332	24.98	981	23.22
2353	25.12	983	23.46
2348	25.26	994	24.06
2367	25.86	999	24.33
2384	26.33	1018	24.57
2389	26.68	1032	24.89

Regression Output (TEMP):

Constant	-44.6493
Std Err of Y Est	0.319090
R Squared	0.982257
No. of Observations	20
Degrees of Freedom	18
X Coefficient(s)	0.029735
Std Err of Coef.	0.000941

Regression Output (RH):

Constant	-14.1042
Std Err of Y Est	0.205980
R Squared	0.990914
No. of Observations	20
Degrees of Freedom	18
X Coefficient(s)	0.038104
Std Err of Coef.	0.000859

APPENDIX A3. CALIBRATION FOR HT-220 PRIOR TO TURKEY TRIAL

CAL2 FOR SENSOR #1 (TEMP)

A/D	TEMP (°C)
3160	23
3186	23.36
3204	23.59
3219	23.87
3225	24.02
3240	24.29
3248	24.58
3274	25.02
3316	25.56
3327	26.03
3310	26.31
3356	26.56
3375	26.84
3380	27
3390	27.32
3407	27.5
3424	27.81
3436	28.01
3446	28.21
3468	28.51

CAL2 FOR SENSOR #1 (RH)

A/D	RH (%)
1630	25
1658	26
1676	26.5
1696	27
1700	27.5
1710	28
1730	28.15
1760	29.1
1770	29.6
1810	30.5
1830	31
1850	32
1867	32.5
1890	33
1900	33.5
1928	34.5
1953	34.6
2000	35.5
2010	37
2054	38

Regression Output (TEMP):

Constant	-36.0608
Std Err of Y Est	0.173861
R Squared	0.991021
No. of Observations	20
Degrees of Freedom	18
X Coefficient(s)	0.018656
Std Err of Coef.	0.000418

Regression Output (RH):

Constant	-23.5990
Std Err of Y Est	0.289079
R Squared	0.994556
No. of Observations	20
Degrees of Freedom	18
X Coefficient(s)	0.029952
Std Err of Coef.	0.000522

APPENDIX A4. CALIBRATION FOR HT-46 PRIOR TO TURKEY TRIAL

CAL2 FOR SENSOR#2 (TEMP)

A/D	TEMP (°C)
2307	23.74
2310	24
2327	24.46
2330	24.77
2332	25.04
2346	25.48
2379	26
2386	26.5
2392	27
2414	27.5
2432	28.05
2442	28.6
2467	28.8
2469	29
2483	29.2
2474	29.5
2484	29.9
2507	30.01
2521	30.5
2523	30.69

CAL2 FOR SENSOR#2 (RH)

A/D	RH (%)
1197	26.53
1212	27.2
1231	27.55
1248	28.03
1255	28.5
1285	29.24
1291	30
1297	30.55
1310	31.06
1338	31.5
1354	32.17
1374	32.36
1393	33.07
1423	34.02
1437	35.11
1472	36.03
1501	36.9
1527	38.08
1562	38.5
1583	39.19

Regression Output (TEMP):

Constant	-47.6056
Std Err of Y Est	0.240892
R Squared	0.989577
No. of Observations	20
Degrees of Freedom	18
X Coefficient(s)	0.031057
Std Err of Coef.	0.000751

Regression Output (RH):

Constant	-13.2786
Std Err of Y Est	0.323176
R Squared	0.993739
No. of Observations	20
Degrees of Freedom	18
X Coefficient(s)	0.033388
Std Err of Coef.	0.000624

APPENDIX A5. CALIBRATION FOR HYGRO-M1 DEW POINT HYGROMETER

CAL1 FOR DEWPOINT (TEMP) CAL2 FOR DEWPOINT (TEMP)

BROILER CHICKEN TRIAL TURKEY TRIAL

A/D	DPT (°C)	A/D	DPT (°C)
2520	13.3	2023	-2.3
2524	13.5	2020	-2.2
2540	13.7	2038	-1.7
2547	14.1	2042	-1.6
2562	14.5	2042	-1.6
2570	14.7	2051	-1.4
2578	14.9	2109	0.4
2578	15.1	2110	0.5
2581	15.2	2107	0.5
2584	15.3	2107	0.5
2587	15.4	2113	0.6
2594	15.5	2120	0.7
2597	15.6	2135	1.4
2598	15.7	2138	1.4
2601	15.8	2142	1.5
2603	15.8	2150	1.8
2608	15.9	2172	2.5
2617	16	2188	2.9
2608	16	2210	3.5
2608	16.1	2220	3.9

Regression Output (Broiler chicken trial):

Constant	-63.4272
Std Err of Y Est	0.101007
R Squared	0.987308
No. of Observations	20
Degrees of Freedom	18
X Coefficient(s)	0.030435
Std Err of Coef.	0.000813

Regression Output (Turkey Trial):

Constant	-64.8664
Std Err of Y Est	0.072549
R Squared	0.998586
No. of Observations	20
Degrees of Freedom	18
X Coefficient(s)	0.030983
Std Err of Coef.	0.000274

APPENDIX B

PERFORMANCE OF HT-220 IN A MISTED ENVIRONMENT

APPENDIX B. PERFORMANCE OF HT-220 IN A MISTED ENVIRONMENT

TIME	RH SENSOR	RH REFERENCE
0	64.37	64.25
4	64.98	64.93
8	66.03	66.12
12	66.94	66.53
16	67.26	67.08
20	67.42	67.53
24	68.02	67.97
28	69.03	69.17
32	73.87	74.84
36	76.06	77.95
40	76.49	79.51
44	77.78	80.63
48	79.34	81.72
52	80.13	81.46
56	81.17	82.29
60	82.47	83.17
64	83.15	83.8
68	83.64	84.45
72	84.14	84.64
76	84.32	84.98
80	85.13	85.96
84	85.97	86.24
88	86.08	86.96
92	86.61	87.07
96	87.31	87.98
100	88.14	88.94
104	89.1	90.42
108	92.16	93.31
112	103.2	95.57
116	103.2	95.11
120	103.2	85.04
124	103.2	80.02
128	103.2	79.45
132	103.2	77.51
136	103.2	76.4
140	103.2	76.14
144	103.2	74.76

Regression Output:

Constant		2.676273
Std Err of Y Est		0.787777
R Squared		0.991869
No. of Observations		28
Degrees of Freedom		26
X Coefficient(s)	0.970736	
X Coefficient(s)	0.955977	
Std Err of Coef.	0.016974	

APPENDIX C.

THE PERFORMANCE OF HT-220 AND HT-46 IN BROILER CHICKEN AND TURKEY TRIALS

THE TWO SENSORS WERE RUN FOR SEVEN WEEKS AND THE DATA WERE COLLECTED AT TWO CONSECUTIVE DAYS IN EACH WEEK.

TEMP1: Pt100 RTD READING FROM HT-220

TEMP2: Pt100 RTD READING FROM HT-46

RH1: RH READING FROM HT-220

RH2: RH READING FROM HT-46

DPT: DEW POINT TEMPERATURE READING FROM HYGRO-M1

RHref: RH REFERENCE CALCULATED FROM TEMP1 AND DPT

BROILER CHICKEN TRIAL (WEEK1).

TIME	TEMP	RH	DPT	RHref
0	23.15	35.14	7.16	35.68
	23.59	34.12	7.08	34.56
	23.36	34.73	7.02	34.89
	22.71	38.49	7.80	38.27
	23.39	37.15	8.68	39.00
	23.48	36.32	7.78	36.50
6	22.64	38.3	7.42	37.45
	22.77	37.12	7.17	36.54
	22.38	37.37	7.08	37.17
	23.48	34.12	7.13	34.91
	23.45	34.34	6.75	34.04
	22.66	36.1	6.87	36.03
12	23.96	31.73	6.48	32.41
	23.81	31.6	6.47	32.70
	24.29	30.77	6.47	31.76
	24.14	29.56	6.46	32.03
	24.44	30.2	6.46	31.45
	24.38	29.59	6.45	31.54
18	26.24	28.86	6.54	28.42
	26.16	27.67	6.43	28.33
	26.29	28.19	6.53	28.32
	27.52	26.14	7.34	27.85
	26.31	27.9	6.42	28.07
	25.89	29.65	6.58	29.10
0	25.76	30.16	6.93	30.04
	25.45	30.8	6.63	29.97
	25.39	32.97	8.01	33.06
	25.28	31.38	6.63	30.27
	25.08	31.38	6.88	31.16
	24.95	31.22	6.94	31.54
6	24.88	31.92	7.02	31.85
	24.88	31.66	6.88	31.54
	24.75	31.47	6.80	31.61
	25.59	30.26	6.78	30.03
	26.16	29.88	7.12	29.71
	25.3	32.52	7.40	31.89
12	25.57	32.59	7.49	31.56
	25.7	32.17	7.31	30.95
	25.68	32.43	7.69	31.79
	25.72	32.36	7.57	31.47
	25.79	32.14	7.66	31.52
	25.92	32.43	8.26	32.57
18	25.96	32.24	8.13	32.23
	26.12	31.95	7.74	31.09
	26.2	32.43	7.94	31.36
	26.38	32.11	8.29	31.79
	26.27	32.01	8.06	31.49
	26.03	32.43	8.13	32.09

BROILER CHICKEN TRIAL (WEEK2)

TIME	TEMP1	RH1	DEPT	TEMP2	RH2	RHref
0	24.42	24.96	3.18	25.19	25.44	25.02
	24.35	24.36	2.64	24.93	25.13	24.18
	24.36	24.23	2.42	24.38	24.43	23.79
	24.31	25.28	2.51	24.47	25.10	24.02
	24.66	24.74	2.83	24.26	25.71	24.06
	24.71	25.19	3.10	24.80	25.34	24.45
6	24.93	26.08	3.68	25.47	26.45	25.14
	25.02	25.7	3.80	25.93	26.45	25.22
	25.08	25.79	4.04	25.05	26.08	25.57
	25.06	24.87	3.50	25.74	25.64	24.64
	25.21	25.22	3.99	25.71	25.27	25.28
	25.17	24.29	3.05	25.44	24.76	23.71
12	25.12	24.52	3.33	25.78	25.07	24.25
	25.08	24.68	3.41	25.29	25.34	24.45
	24.9	24.42	2.48	25.23	25.10	23.13
	24.86	25.89	3.28	24.86	26.42	24.55
	24.71	25.95	3.03	25.50	26.72	24.34
	25.23	25.09	3.99	25.26	25.37	25.25
18	24.95	26.11	4.37	25.44	26.11	26.37
	24.6	26.3	3.97	24.56	26.52	26.17
	25.37	25.22	3.90	26.53	25.91	24.88
	24.53	25.7	3.69	25.05	25.98	25.78
	25.56	27.61	5.63	26.47	27.73	27.77
	24.6	26.65	4.08	25.11	26.75	26.39
0	22.79	27.61	3.10	23.69	27.60	27.44
	24.05	27.45	4.25	24.11	27.56	27.59
	23.54	30.1	5.47	23.90	30.63	31.00
	23.52	29.43	5.38	24.20	30.33	30.84
	23.94	29.01	4.57	24.20	30.40	28.42
	24.31	28.89	5.49	24.69	29.65	29.64
6	23.87	23.65	1.63	24.05	24.36	23.15
	22.88	26.81	2.83	23.09	27.53	26.78
	23.48	23.14	1.34	23.71	24.29	23.21
	22.86	25.47	2.35	23.20	26.42	25.90
	23.39	23.56	1.34	23.84	23.92	23.34
	23.67	24.9	2.31	24.20	25.24	24.61
12	23.28	27.67	4.13	23.86	28.61	28.67
	23.39	27.29	4.04	24.66	28.07	28.30
	23.59	28.66	5.08	24.20	29.28	30.07
	23.41	28.92	4.68	24.29	29.32	29.56
	24.2	25.79	3.59	24.93	26.21	26.11
	23.67	26.91	3.85	24.47	26.96	27.44
18	23.89	27.83	4.16	24.23	28.24	27.68
	24.09	26.69	4.16	24.47	26.79	27.36
	24.16	26.88	4.61	25.02	27.43	28.12
	24.31	26.4	4.17	25.08	26.89	27.01
	24.47	25.73	4.26	25.32	26.65	26.93
	24.35	24.99	3.66	25.65	25.20	26.00

BROILER CHICKEN TRIAL (WEEK3)

TIME	TEMP1	RH1	DPT	TEMP2	RH2	RHref
0	24.6	22.67	0.80	25.11	23.52	20.87
	24.73	21.29	0.22	24.75	21.42	19.85
	24.77	22.92	0.70	24.81	22.94	20.51
	24.73	21.8	1.13	24.27	22.57	21.2
	24.77	21.52	0.61	24.27	21.69	20.37
	24.9	21.64	1.02	25.51	22.10	20.83
6	25.54	22.38	1.81	26.54	22.77	21.22
	25.13	20.97	0.98	25.05	21.53	20.48
	25.08	20.91	1.28	26.02	21.26	20.99
	24.91	20.91	0.07	25.48	21.83	19.43
	25.19	21.04	0.62	24.96	21.73	19.89
	25.1	21.64	0.79	24.90	22.40	20.24
12	24.93	20.97	0.50	24.66	21.42	20.02
	25.02	21.36	1.99	25.96	22.03	22.17
	25.15	20.46	1.53	25.90	21.12	21.29
	24.93	22.54	1.73	24.45	22.61	21.88
	25.89	20.43	1.28	25.60	20.68	20.01
	24.93	22.06	1.11	25.93	22.13	20.93
18	25.68	21.42	1.28	26.81	22.07	20.26
	24.77	20.72	0.22	25.26	21.63	19.8
	24.93	22.09	0.92	25.42	22.00	20.64
	25.17	21.39	2.11	24.51	22.54	22.17
	24.95	20.94	0.69	25.99	21.12	20.28
	25.63	20.21	0.38	25.48	20.51	19.03
0	24.77	22.73	0.54	24.27	22.47	20.27
	25.12	21.74	0.72	25.39	22.34	20.12
	25.01	20.21	1.31	26.11	20.85	21.13
	24.77	20.4	0.84	25.96	20.82	20.71
	25.87	20.65	1.08	26.60	21.02	19.75
	25.78	20.91	1.51	26.44	21.69	20.48
6	24.62	21.23	0.94	25.72	22.07	21.05
	24.58	22.06	1.32	24.78	22.67	21.7
	25.96	19.79	1.01	26.14	20.21	19.54
	25.54	20.11	0.08	25.20	20.48	18.73
	25.13	20.56	1.63	25.45	20.95	21.46
	24.84	20.4	0.73	25.20	21.05	20.47
12	24.71	20.81	1.25	24.42	20.95	21.42
	25.08	22.22	1.34	25.57	22.61	21.09
	25.72	20.3	1.09	25.93	20.45	19.93
	25.85	19.95	1.73	26.90	20.85	20.72
	25.48	22.03	3.07	25.42	22.74	23.31
	25.21	21.52	2.54	24.78	21.93	22.8
18	24.79	21.48	1.78	24.60	21.80	22.14
	24.16	22.31	1.27	24.33	22.98	22.17
	24.33	20.81	0.76	25.84	21.49	21.14
	24.9	20.5	1.06	24.72	20.58	20.88
	24.22	22.19	0.96	24.42	22.57	21.59
	23.36	22.31	0.89	23.57	22.84	22.63

BROILER CHICKEN TRIAL (WEEK4)

TIME	TEMP1	RH1	DPT	TEMP2	RH2	RHref
0	23.72	20.21	-1.44	24.70	20.55	18.67
	24.55	25.54	1.30	24.19	25.17	21.7
	23.56	24.23	0.33	23.86	25.57	21.47
	24.55	23.4	0.52	24.61	23.65	20.51
	25.02	22.12	-0.26	26.09	22.40	18.84
	24.69	23.3	1.01	24.55	24.06	21.08
6	24.11	23.21	0.52	24.67	23.58	21.06
	24.93	22.67	1.08	25.49	22.81	20.88
	24.24	22.7	0.65	24.58	23.38	21.09
	24	22.09	0.64	24.10	22.40	21.39
	24.38	22.98	0.83	25.58	23.99	21.19
	24.2	24.45	1.42	24.22	24.87	22.36
12	24.18	25.82	2.05	25.13	25.81	23.41
	24.07	24.9	1.08	24.76	25.17	21.98
	24.18	23.91	0.86	24.25	24.12	21.49
	24.24	23.75	1.96	25.04	24.36	23.18
	24.22	22.98	0.99	24.19	23.21	21.64
	24.2	22.95	0.99	24.85	22.87	21.67
18	25.48	23.34	2.32	25.37	23.08	22.1
	25.39	22.98	2.64	26.85	22.84	22.72
	25.24	23.18	1.39	26.43	22.81	20.96
	25.19	23.97	2.33	26.13	24.22	22.49
	25.1	23.11	2.05	24.94	23.75	22.16
	24.95	22.86	1.83	25.22	23.45	22.01
0	24.58	21.2	0.71	25.52	21.36	20.75
	24.9	23.85	1.67	25.55	23.79	21.83
	24.25	23.78	0.73	25.70	24.02	21.21
	25.46	23.08	2.07	26.13	23.62	21.73
	24.97	22.7	1.02	25.79	22.77	20.74
	24.35	23.24	1.49	25.70	23.85	22.26
6	24.42	22.06	0.93	25.25	22.37	21.29
	25.32	21.45	1.11	26.49	21.56	20.45
	25.52	23.56	1.89	26.55	24.06	21.37
	24.53	21.77	1.52	25.19	22.03	22.07
	25.15	21.61	1.20	26.22	21.76	20.79
	25.52	22.38	2.29	26.94	22.64	22
12	24.8	25.5	2.35	25.64	25.44	23.06
	24.69	24.29	2.38	24.46	24.39	23.26
	24.66	24.36	2.36	25.46	24.26	23.26
	24.57	24.01	2.36	24.88	24.06	23.39
	24.64	24.68	2.36	24.98	25.00	23.29
	24.68	24.99	2.45	24.40	25.17	23.39
18	26.14	22.09	2.82	26.88	21.90	22.02
	25.96	22.25	2.70	26.58	22.10	22.06
	26.01	21.1	1.64	26.16	21.69	20.39
	26.18	22.22	2.42	26.25	21.93	21.35
	25.96	21.71	1.64	26.09	22.07	20.45
	25.7	20.65	0.58	26.28	20.58	19.24

BROILER CHICKEN TRIAL (WEEK5)

TIME	TEMP1	RH1	DPT	TEMP2	RH2	RHref
0	21.69	29.94	2.88	22.63	30.70	28.90
	21.91	33.77	3.93	21.60	34.48	30.72
	23.17	36.67	6.32	23.44	36.94	33.63
	23.48	34.44	5.80	22.81	35.02	31.84
	23.65	34.06	6.03	24.05	34.65	32.01
	23.52	34.47	5.64	23.32	35.19	31.41
6	23.41	36.74	7.40	23.69	37.68	35.70
	23.32	37.25	7.22	22.84	37.99	35.44
	23.21	37.47	7.25	23.69	38.19	35.76
	23.26	36	6.70	23.05	37.31	34.33
	23.28	36.99	6.73	23.44	37.24	34.37
	23.32	37.31	7.03	23.45	37.82	34.98
12	23.37	41.71	8.16	23.82	42.20	37.70
	23.7	44.07	9.14	23.02	44.33	39.50
	23.81	42.83	9.05	24.75	43.62	38.98
	23.91	42.26	8.95	24.45	42.64	38.51
	24.07	42.03	8.95	24.96	42.37	38.12
	24.24	43.31	9.62	25.02	43.65	39.48
18	26.58	42.64	12.87	25.78	42.34	42.64
	26.49	44.23	12.87	26.99	43.52	42.87
	26.4	44.71	13.28	26.66	44.63	44.29
	26.22	44.74	13.07	27.01	44.97	44.13
	25.92	44.36	12.59	26.32	44.26	43.54
	25.83	44.27	12.59	26.69	43.89	43.78
0	19.76	48.92	8.68	20.45	49.45	48.71
	19.93	50.01	9.19	20.36	49.52	49.88
	21.45	54	11.63	21.66	53.71	53.48
	21.93	54.6	12.22	22.57	54.08	54.02
	21.84	51.83	11.25	22.24	52.36	50.91
	21.8	50.52	10.93	22.39	50.77	49.97
6	19.87	53.58	10.10	20.06	54.08	53.24
	19.95	53.93	10.52	19.30	53.87	54.48
	20.02	53.93	10.39	21.00	54.14	53.77
	19.67	52.85	9.41	20.32	53.77	51.46
	19.45	51.45	9.13	21.01	52.96	51.19
	19.56	53.14	9.73	20.88	54.18	52.94
12	22.93	52.43	12.17	23.05	52.56	50.65
	23.34	52.69	12.64	24.09	52.22	50.97
	23.41	51.73	11.97	24.48	51.61	48.57
	23.83	51.32	12.53	23.81	51.28	49.14
	23.98	51.73	13.14	24.02	51.82	50.66
	23.89	49.34	12.13	24.93	49.79	47.66
18	26.18	46.5	13.35	26.32	46.69	45.07
	26.2	47.07	13.35	27.57	46.45	45.02
	26.23	48.67	14.42	27.81	48.38	48.18
	26.12	46.66	13.54	26.17	47.73	45.78
	25.98	47.78	13.64	26.05	47.26	46.47
	25.81	46.76	13.35	26.77	46.59	46.07

BROILER CHICKEN TRIAL (WEEK6)

TIME	TEMP1	RH1	DPT	TEMP2	RH2	RHref
0	22.07	48.77	9.78	22.25	48.81	45.52
	23.48	51.67	12.90	23.79	51.48	51.39
	23.5	47.55	11.28	24.13	48.00	46.13
	23.78	47.52	11.79	24.03	48.38	46.91
	23.65	47.27	11.38	24.03	47.87	46.01
	23.67	46.6	11.37	24.16	47.19	45.95
6	22.59	51.32	11.62	21.79	52.52	49.86
	22.48	50.55	11.02	22.70	51.55	48.23
	22.51	50.74	11.24	23.10	52.05	48.84
	22.46	50.33	11.15	23.37	50.80	48.70
	22.24	50.74	10.93	22.28	51.48	48.64
	21.89	51.09	10.42	21.52	51.85	48.05
12	22.71	54.57	12.60	23.28	54.28	52.79
	22.86	54.92	12.79	22.89	55.02	52.97
	22.97	55.43	12.97	23.70	55.29	53.27
	22.93	56.42	13.16	22.87	57.58	54.06
	22.92	54.13	12.79	23.61	54.04	52.79
	23.06	52.4	12.59	23.85	53.57	51.66
18	24.55	29.01	5.92	25.64	30.46	30.10
	25.45	27.77	5.28	26.67	28.20	27.28
	24.82	28.86	4.62	25.30	30.43	27.04
	24.93	28.86	5.29	25.12	29.89	28.16
	24.77	28.73	5.01	25.49	30.23	27.88
	24.66	28.92	4.92	25.27	29.52	27.88
0	21.95	25.6	0.98	22.78	26.52	24.82
	23.08	27.07	2.55	24.46	27.39	25.94
	23.15	27.67	3.55	24.67	28.95	27.72
	22.99	26.08	2.78	23.14	27.09	26.51
	23.03	26.59	2.46	24.24	27.90	25.85
	24.09	25.38	4.16	25.17	26.62	27.36
6	23.47	26.27	2.57	24.36	27.19	25.37
	23.54	26.78	2.47	24.35	27.93	25.08
	23.61	26.11	2.66	23.55	27.60	25.31
	23.61	26.81	2.72	24.06	28.07	25.43
	24.53	27	4.54	24.79	28.37	27.36
	23.85	25.86	2.46	23.96	27.19	24.60
12	24.69	26.49	3.13	25.33	26.72	24.54
	24.84	27.67	3.36	24.39	28.81	24.72
	24.88	27.1	3.85	25.97	27.56	25.52
	24.82	26.91	3.62	25.27	27.70	25.20
	24.8	26.4	3.75	25.88	26.86	25.46
	24.97	26.75	3.32	25.51	27.13	24.46
18	26.05	25.7	3.44	26.82	25.78	23.14
	25.94	24.42	3.64	26.24	25.47	23.62
	25.96	25.03	3.15	26.48	25.47	22.79
	25.87	24.68	2.12	26.24	24.73	21.28
	25.89	23.97	2.54	26.94	24.12	21.91
	25.9	23.69	2.60	26.69	24.06	21.99

BROILER CHICKEN TRIAL (WEEK7)

TIME	TEMP1	RH1	DPT	TEMP2	RH2	RHref
0	24.69	24.8	2.54	24.86	24.80	23.52
	24.6	25.25	2.44	25.14	25.64	23.49
	25.61	27.16	4.55	26.89	27.70	25.68
	25.68	27.1	4.25	26.23	26.89	25.04
	25.63	25.57	3.44	26.47	25.61	23.72
	25.68	27	3.44	26.99	27.02	23.64
6	25.54	24.9	2.08	25.90	25.20	21.64
	25.54	25.6	3.62	26.14	26.01	24.14
	25.39	25.03	2.93	26.17	26.01	23.20
	25.32	24.87	2.32	26.14	25.37	22.30
	25.32	24.93	2.22	25.56	24.73	22.14
	25.15	24.58	2.09	25.59	25.17	22.17
12	25.52	25.19	2.47	26.23	25.61	22.28
	25.54	23.46	2.18	26.96	23.82	21.79
	25.48	22.35	1.03	26.38	23.01	20.13
	25.19	20.56	-0.08	25.38	21.02	18.90
	25.13	20.05	-0.70	26.41	20.61	18.12
	25.28	18.96	-1.11	26.29	19.74	17.43
18	25.68	18.1	-2.20	26.14	18.29	15.70
	25.72	17.94	-2.94	26.74	18.73	14.82
	25.79	17.66	-2.61	26.71	18.09	15.13
	25.76	17.72	-1.86	26.99	17.68	16.02
	25.74	17.85	-2.20	26.35	17.98	15.64
	25.65	18.2	-2.10	25.80	19.03	15.85
0	22.55	20.43	-3.27	23.11	20.95	17.49
	22.62	19.38	-2.38	23.32	19.87	18.61
	23.39	21.93	-1.16	24.29	22.64	19.44
	23.3	21.04	-0.90	24.02	21.66	19.93
	24.29	20.56	0.10	25.86	20.82	20.21
	23.5	20.94	-1.51	24.47	21.22	18.83
6	23.69	21.48	-1.21	24.56	22.17	19.03
	23.98	20.08	-1.33	24.17	20.95	18.53
	23.83	20.81	-0.50	24.72	21.19	19.88
	24.4	20.65	0.19	25.11	20.55	20.21
	23.69	21.2	-0.59	24.81	22.27	19.92
	24.57	19.95	1.54	24.99	20.72	22.05
12	23.34	21.96	-0.96	24.05	23.04	19.79
	23.48	22.03	-0.68	24.44	22.37	20.04
	23.32	22.15	-1.10	24.32	22.50	19.62
	23.26	23.78	-1.06	24.05	24.29	19.74
	23.3	23.56	-0.54	24.26	24.16	20.47
	23.32	22.09	-1.29	24.02	22.91	19.34
18	25.78	25.03	2.86	26.50	26.08	22.55
	25.72	23.34	2.00	26.74	23.92	21.29
	25.76	23.05	1.90	26.44	23.18	21.09
	25.79	23.72	2.52	26.83	23.85	22.00
	25.76	23.78	2.43	26.53	24.02	21.90
	25.78	25.06	2.86	26.62	25.61	22.55

TURKEY TRIAL (WEEK 1)

TIME	TEMP1	RH1	DPT	TEMP2	RH2	RHref
0	21.32	19.89	-2.46	21.75	20.98	20.03
	22.16	23.3	-0.24	21.57	23.79	22.41
	21.52	29.62	2.62	21.45	28.46	28.67
	20.22	27.42	0.84	22.36	27.42	27.32
	19.1	28.76	0.44	21.93	28.91	28.45
	19.18	25.61	-0.85	20.39	26.39	25.76
6	22.04	20.11	-2.42	21.02	21.02	19.23
	21.71	19.12	-2.79	22.39	19.77	19.08
	22.51	21.58	-0.86	22.74	21.53	20.97
	22.48	22.86	0.02	23.08	23.99	22.4
	22.49	23.11	0.29	22.45	23.3	22.84
	22	19.31	-1.91	21.45	20.34	20.01
12	19.38	22.56	-2.41	21.84	21.31	22.67
	19.56	30.69	1.93	20.99	30.11	30.78
	19.2	31.55	2.06	20.72	31.29	31.77
	19.2	33.19	2.52	21.81	32.25	32.85
	18.83	29.29	1.00	20.99	30.11	30.13
	19.25	28.97	0.85	21.05	27.35	29.04
18	21.73	23.65	0.17	21.69	23.59	23.71
	22.15	23.88	0.72	21.11	24.51	24.06
	23.01	20.56	-1.24	22.36	20.49	19.78
	22.15	25.15	1.19	21.63	25.34	24.89
	22.46	25.19	1.68	21.63	25.48	25.3
	23.36	21.8	-0.09	23.41	21.51	21.08
0	24.79	18.29	-0.10	25.08	19.59	19.33
	25.59	18.55	0.31	25.08	19.49	18.99
	23.58	23.91	1.17	24.63	22.15	22.79
	22.51	22.63	0.08	22.14	23.1	22.46
	23.47	22.44	0.70	23.02	22.53	22.17
	22.42	23.37	0.96	21.63	24.59	24.07
6	23.59	20.81	-0.45	24.75	20.45	20.24
	23.56	19.73	-0.32	23.41	20.9	20.47
	22.13	21.33	-0.92	21.81	22.1	21.36
	23.52	21.23	0.22	23.35	21.94	21.34
	24.22	17.75	-1.20	23.81	18.55	18.44
	24.84	20.85	1.10	23.14	21.59	21.02
12	21.16	25.25	0.35	22.29	24.34	24.88
	21.65	23.97	0.03	22.26	24.2	23.59
	23.54	23.37	1.67	24.53	23.43	23.68
	23.61	17.37	-1.72	25.11	17.74	18.41
	23.56	22.35	0.89	24.96	22.42	22.36
	22.75	23.43	1.01	22.6	24.41	23.68
18	18.77	32.67	1.96	19.9	32.23	32.42
	18.98	40.05	5.44	19.72	40.59	40.91
	18.54	43.31	5.68	19.69	43.13	42.76
	18.32	39	4.28	19.48	29.32	39.32
	18.41	44.04	6.16	19.93	44.46	44.57
	18.77	43.05	5.91	19.54	43.61	42.84

TURKEY TRIAL (WEEK 2)

TIME	TEMP1	RH1	DPT	TEMP2	RH2	RHref
0	20.67	37.91	5.46	21.45	36.98	36.89
	20.39	43.27	7.11	20.78	42.47	42.08
	20.79	47.99	9.17	21.21	48.02	47.24
	21.63	51.37	10.79	21.48	50.38	50.02
	20.06	45.28	7.86	20.84	45.85	45.21
	20.54	51.44	9.77	20.9	49.77	49.96
6	21.64	49.04	10.66	21.11	51.02	49.58
	19.78	49.65	8.68	20.09	49.21	48.65
	20.47	48.31	9.22	20.48	49.06	48.36
	21.82	50.13	10.62	21.72	48.98	48.88
	20.81	46.33	8.64	21.11	45.76	45.51
	21.31	46.24	9.48	21.66	47.91	46.72
12	20.75	33.09	3.79	20.66	33.19	32.66
	19.73	30.76	1.88	20.24	30.96	30.36
	19.75	28.81	0.90	20.78	28.88	28.25
	20.91	27.7	1.53	21.96	27.83	27.52
	21.17	30.09	2.46	21.96	28.63	28.94
	20.83	30.19	1.85	20.9	30.18	28.29
18	22.18	30.76	3.53	23.2	29.44	29.37
	22.84	28.94	4.25	23.05	30.12	29.68
	21.85	27.41	2.42	22.36	27.92	27.68
	22.95	31.18	4.58	23.23	30.05	30.17
	21.84	29.33	3.59	22.08	30.76	30.12
	21.73	29.61	3.06	22.2	30.01	29.19
0	20.28	25.72	0.18	22.17	25.92	25.94
	21.07	28.62	1.78	21.72	28.13	27.75
	21.03	26.84	1.59	22.29	27.62	27.44
	21.3	30.06	2.61	21.36	29.63	29.03
	21.32	32.58	4.13	22.48	32.88	32.3
	20.9	26.77	0.86	22.54	26.74	26.24
6	21.23	25.56	1.30	21.08	27.02	26.53
	21.3	26.2	1.86	22.96	25.95	27.51
	21.56	29.45	2.41	21.39	29.72	28.17
	21.32	28.11	2.24	22.51	29.00	28.24
	21.32	29.64	2.34	20.99	29.38	28.44
	21.21	27.28	2.06	21.27	28.56	28.06
12	21.93	28.75	3.05	22.9	28.91	28.83
	22.04	31.46	3.71	21.99	30.98	29.99
	22.15	27.47	2.59	23.69	27.92	27.52
	22.64	29.2	3.79	22.6	29.46	29.08
	22.68	24.79	1.51	22.48	25.65	24.66
	23.47	28.08	3.90	24.17	27.97	27.87
18	25.06	24.35	3.90	24.69	26.12	25.34
	25.01	23.33	3.07	24.53	24.64	23.97
	25.06	24.16	2.24	25.5	22.71	22.52
	24.99	24.86	3.28	25.68	24.26	24.35
	25.04	23.04	2.43	25.9	22.86	22.86
	24.53	23.71	2.70	25.32	24.12	24.03

TURKEY TRIAL (WEEK 3)

TIME	TEMP1	RH1	DPT	TEMP2	RH2	RHref
0	20.52	35.62	3.83	21.42	34.25	33.21
	20.83	33.07	4.04	20.42	35.51	33.08
	20.55	32.17	3.19	20.3	32.87	31.69
	20.61	31.06	2.89	19.84	32.27	30.9
	20.55	33.19	3.07	20.75	32.66	31.41
	20.59	32.97	3.17	19.45	32.35	31.55
6	20.33	32.36	2.68	19.69	32.75	30.97
	20.81	33.83	3.60	20.33	34.11	32.1
	20.64	32.94	2.94	20.42	33.03	30.95
	20.39	31.02	2.70	20.87	31.94	30.89
	19.98	29.68	1.49	20.3	30.36	29.07
	20.5	33.83	3.59	20.36	34.51	32.69
12	21.49	33.48	4.36	22.12	33.62	32.48
	21.96	32.72	4.56	22.08	33.44	32
	22	33.48	4.53	22.69	32.46	31.86
	22.26	32.94	4.71	21.33	34.04	31.77
	21.91	32.36	4.19	22.48	32.23	31.29
	21.95	32.62	4.08	21.51	32.49	30.97
18	22.26	33.93	4.74	21.72	33.85	31.82
	21.84	30.77	3.54	21.84	31.67	30.01
	21.71	33.35	4.16	21.21	33.71	31.6
	21.73	33.71	4.43	21.75	34.41	32.16
	21.69	32.78	4.48	21.75	33.39	32.35
	21.45	33.16	4.31	21.05	34.54	32.45
0	20.9	39.8	5.98	20.84	39.88	37.72
	21.23	39.32	6.81	21.3	40.62	39.14
	21.29	41.17	7.52	20.96	42.26	40.96
	21.18	39.48	7.10	20.57	41.48	40.05
	20.68	38.91	5.34	20.09	38.64	36.57
	20.68	38.4	5.21	20.78	37.56	36.24
6	20.83	38.94	5.48	21.48	37.43	36.59
	21.01	39.51	6.06	20.93	39.86	37.68
	20.81	38.24	5.63	20.96	38.53	37.01
	20.68	38.78	5.47	20.12	38.62	36.9
	20.74	36.58	4.91	21.57	36.25	35.36
	20.42	34.31	4.09	21.45	35.48	34.05
12	20.48	40.02	6.02	21.11	39.25	38.81
	20.28	39.22	5.57	21.3	39.38	38.09
	20.39	41.24	6.63	19.75	41.35	40.71
	20.26	41.68	6.18	19.42	41.54	39.79
	20.37	40.37	6.10	20.63	40.47	39.3
	20.24	37.79	5.26	21.08	38.26	37.37
18	21.19	32.59	3.32	20.99	31.54	30.74
	21.43	33.67	3.97	21.81	33.73	31.72
	20.88	31.34	2.77	21.87	31.18	30.12
	21.36	33.96	4.45	20.42	35.52	32.94
	21.08	32.36	3.88	21.51	33.83	32.21
	20.97	33.39	3.60	21.48	32.47	31.79

TURKEY TRIAL (WEEK 4)

TIME	TEMP1	RH1	DPT	TEMP2	RH2	RHref
0	21.05	36.03	4.87	21.27	36.18	34.58
	21.27	34.82	4.66	21.27	35.65	33.63
	21.14	33.8	3.83	20.36	33.25	31.96
	21.34	35.2	4.66	20.57	35.88	33.47
	21.01	33.86	3.64	20.33	32.98	31.79
	21.14	35.65	4.54	20.99	35.39	33.61
6	20.75	34.95	4.35	21.42	36.1	33.97
	20.79	32.65	3.23	20.24	33.85	31.3
	20.57	31.76	2.30	21.05	31.73	29.69
	20.72	31.82	2.91	21.6	32.3	30.74
	20.41	31.63	2.46	20.42	32.4	30.33
	20.7	33.74	3.00	20.81	32.4	30.98
12	19.93	32.88	2.28	19.36	33.43	30.86
	19.71	32.68	2.35	20.3	33.18	31.44
	20.09	31.79	1.97	19.51	32.18	29.87
	19.53	27.42	0.26	20.09	29.67	27.33
	19.65	28.89	0.12	20.51	28.91	26.86
	19.93	32.17	2.56	20.39	34.02	31.47
18	20.72	38.84	5.80	20.06	39.5	37.65
	20.24	34.47	3.43	20.93	33.94	32.86
	20.59	38.08	5.28	21.21	37.66	36.61
	20.08	35.56	3.64	20.27	34.75	33.68
	20.15	35.75	3.95	20.54	35.97	34.27
	20.04	34.12	2.50	20.18	33.75	31.13
0	20.08	39.67	5.25	20.33	38.47	37.71
	20.24	39.54	5.30	20.36	39.39	37.46
	20.33	40.34	6.15	19.63	40.7	39.52
	20.08	40.88	5.83	20.45	40.65	39.27
	20.53	40.15	6.07	20.33	40.02	38.84
	19.69	36.86	3.80	20.15	35.8	34.88
6	20.33	40.98	5.50	20.72	39.59	37.79
	19.4	35.72	3.67	19.72	36.62	35.21
	19.05	37.06	3.54	19.57	35.72	35.66
	19.62	36.86	3.71	20.09	35.78	34.83
	19.58	39.48	5.17	19.36	40.26	38.67
	19.76	36.8	3.75	20.96	36.32	34.62
12	19.6	32.21	2.48	19.09	34.12	31.94
	20.41	36.19	4.35	20.54	35.27	34.68
	19.51	32.33	2.53	19.21	35	32.25
	20	36.57	3.93	20.33	36.35	34.53
	19.87	37.37	4.22	19.99	36.74	35.55
	19.6	34.79	3.05	19.12	34.69	33.27
18	19.21	34.41	2.61	19.3	35.99	33.03
	20.22	32.62	1.92	20.84	31.05	29.54
	19.58	33.03	2.43	19.03	33.88	31.86
	19.21	33.77	2.36	19.81	34.8	32.46
	19.05	36.93	3.19	18.97	37.02	34.78
	19.86	32.75	2.96	19.51	33.99	32.52

TURKEY TRIAL (WEEK 5)

TIME	TEMP1	RH1	DPT	TEMP2	RH2	RHref
0	20.53	33.64	3.72	20.3	34.66	32.94
	20.22	35.91	3.85	19.33	36.38	33.89
	19.73	34.25	1.85	19.9	32.46	30.29
	19.01	34.89	2.80	19.63	34.96	33.90
	20.17	35.17	3.86	19.99	34.69	34.00
	19.27	34.15	2.50	19.36	34.96	32.66
6	18.55	34.25	2.17	18.36	34.86	33.37
	19.69	30.96	0.66	20.6	30.03	27.86
	19.49	35.11	2.43	19.03	35.8	32.06
	19.09	34.63	2.93	19.75	35.36	34.05
	18.79	36.19	2.97	18.24	37.29	34.80
	19.71	32.59	2.56	20.21	34.01	31.91
12	19.34	38.68	3.94	19.84	36.64	36.02
	18.94	38.91	3.99	18.06	40.36	37.06
	18.52	35.01	1.69	18.33	35.49	32.29
	18.99	34.28	2.14	19.06	34.35	32.39
	18.76	31.82	1.52	19.63	34.82	31.42
	18.28	32.59	1.38	19.3	33.04	32.05
18	20.37	31.28	0.97	19.84	30.52	27.32
	19.73	32.72	1.51	19.45	33.81	29.55
	19.91	32.43	1.26	19.54	29.7	28.72
	20.72	32.68	1.96	21.3	31.4	28.72
	19.69	31.85	2.38	19.96	34.28	31.53
	20.64	27.77	0.70	20.6	28.67	26.35
0	19.95	35.87	1.92	19.63	34.01	30.04
	19.42	36.77	3.56	19.93	38.67	34.88
	18.9	34.92	2.38	19.45	35.94	33.13
	19.21	36.1	1.78	18.18	34.15	31.14
	19.82	36.29	3.39	19.96	36.91	33.63
	19.03	33.83	1.83	18.03	34.26	31.59
6	19.65	36.83	3.52	19	37.45	34.30
	19.31	38.81	4.11	19.63	36.88	36.51
	19.31	34.6	2.47	18.3	36.04	32.51
	19.27	34.22	2.14	18.66	33.49	31.83
	19.07	36.42	2.53	18.72	35.26	33.13
	19.53	33.93	2.69	19.18	32.6	32.57
12	19.07	33.99	2.34	18.24	35.77	32.70
	19.36	33.8	3.08	18.18	36.37	33.84
	18.79	33.55	1.78	18.15	34.76	31.95
	19.1	36.1	2.32	18.91	35.45	32.59
	20.22	33.77	2.06	19.15	31.91	29.83
	19.62	36.07	2.53	19	35.14	32.03
18	20.06	32.68	2.82	20.12	33.77	31.81
	19.32	35.81	2.71	18.97	34.96	33.04
	20.08	32.65	2.62	19.57	36.11	31.32
	19.64	33.71	2.73	18.12	35.49	32.44
	19.45	32.78	1.66	19.87	33.06	30.41
	20.06	34.57	2.52	20.09	33.81	31.13

TURKEY TRIAL (WEEK 6)

TIME	TEMP1	RH1	DPT	TEMP2	RH2	RHref
0	21.4	35.17	3.65	20.63	35.25	31.06
	20.37	36	3.82	20.33	36.44	33.51
	19.69	37.02	3.69	18.36	38.08	34.61
	20.35	35.17	3.82	19.06	36.2	33.54
	20.46	38.08	3.84	19.12	36.24	33.37
	19.71	37.69	3.69	20.3	37.96	34.58
6	19.31	36.67	3.60	19.12	36.85	35.22
	20.3	33.55	3.81	19.81	36.58	33.62
	19.31	35.72	2.36	20.54	34.83	32.24
	21.56	32.88	4.08	21.96	35.05	31.71
	20.55	35.62	3.86	20.96	37.14	33.23
	20.31	37.41	3.81	21.03	35.42	33.61
12	19.32	33.19	1.28	20.18	32.08	29.83
	18.98	34.28	1.88	19.51	35.21	31.81
	20.33	31.73	2.04	20.57	32.66	29.58
	20.42	29.97	0.86	20.54	30.66	27.03
	19.73	35.01	3.69	19.42	37	34.54
	18.7	30.71	-0.98	18.45	30.63	26.30
18	20.72	26.02	-1.11	21.9	23.64	22.97
	19.42	31.76	0.03	18.97	28.84	27.06
	21.19	28.34	0.58	20.69	26.95	25.25
	19.62	29.46	-1.04	19.69	29.68	24.72
	20.68	24.8	-1.11	22.2	26.81	23.03
	21.38	23.72	-1.16	21.3	25.69	21.98
0	19.53	28.57	-1.03	19.69	28.43	24.87
	20.17	29.4	-1.07	20.51	24.79	23.83
	19.51	28.41	-1.03	19.33	29.01	24.91
	18.55	26.62	-0.97	19.15	27.93	26.57
	19.49	26.05	-1.03	21.36	27.43	24.94
	19.82	29.14	-1.05	19.96	29.07	24.39
6	19.01	27.99	-1.00	19.39	29.38	25.76
	19.78	27.2	-1.05	21.02	25.4	24.46
	19.8	25.03	-1.05	20.93	26.21	24.43
	17.97	23.34	-5.49	19.12	23.06	19.62
	18.77	23.85	-4.46	19.21	23.83	20.18
	19.18	23.34	-3.31	21.02	24.99	21.46
12	19.56	24.8	-3.40	21.05	24.13	20.82
	18.63	29.81	-0.97	17.58	30.58	26.42
	18.65	30.32	-0.97	17.83	30.24	26.39
	15.69	40.34	-0.80	15.39	35.21	32.24
	13.37	40.57	-0.69	13.09	39.06	37.78
	15.64	36.42	-0.80	14.82	36.14	32.35
18	16.89	31.73	-0.87	17.57	34.05	29.72
	16.52	30.83	-0.85	16.85	34.2	30.47
	16.56	28.86	-1.77	17.24	31.69	28.39
	16.41	27.87	-3.65	17.3	27.99	24.90
	16.35	27.04	-3.22	16.61	29.82	25.82
	16.7	31.66	-0.86	17.33	30.83	30.10

TURKEY TRIAL (WEEK 7)

TIME	TEMP1	RH1	DPT	TEMP2	RH2	RHref
0	18.02	43.79	4.11	18.47	43.05	39.58
	18.99	50.33	7.28	19.05	50.28	46.46
	19.49	51.06	8.13	19.89	49.1	47.73
	18.98	45.83	5.29	18.55	42.78	40.5
	19.58	55.24	9.39	19.01	55.09	51.69
	19.78	55.15	9.64	19.1	55.25	51.92
6	19.2	52.18	7.90	19.4	49.44	47.83
	19.6	57.06	10.04	18.37	57.09	53.93
	18.94	47.81	7.08	18.86	49.49	45.96
	18.94	50.33	7.61	18.89	50.75	47.64
	19.38	54.89	9.29	19.01	55.61	51.97
	19.45	54.51	9.32	18.95	54.81	51.87
12	20.22	44.11	6.29	20.34	44.13	40.2
	19.71	40.37	4.90	20.28	41.11	37.64
	18.99	37.57	2.57	19.43	36.85	33.39
	18.87	40.66	4.04	19.49	39.12	37.34
	18.94	39.42	3.76	18.94	40.04	36.47
	19.36	44.97	5.84	21.01	44.35	41.09
18	19.86	52.05	9.05	19.46	55.03	49.63
	19.62	50.26	7.78	19.7	48.98	46.22
	19.78	56.77	10.00	19.13	56.58	53.17
	19.82	54.73	9.83	20.16	55.83	52.44
	19.86	53.71	9.46	18.77	55.12	51.03
	19.91	53.62	9.28	19.19	53.64	50.26
0	17.29	48.54	5.24	17.89	48.06	44.87
	18.77	60.48	9.88	17.83	58.87	56.18
	19.27	63.19	10.95	18.92	62.35	58.49
	19.98	66.98	12.79	20.25	66.14	63.22
	20	63.51	12.56	19.76	64.05	62.2
	19.6	58.37	10.74	19.92	60.9	56.53
6	19.76	59.29	10.95	19.4	61.07	56.75
	19.43	58.62	10.22	19.58	59.88	55.17
	19.84	61.37	11.30	20.95	63.22	57.79
	19.31	56.9	9.51	19.22	66.32	52.98
	19.23	55.94	9.38	19.86	55.83	52.79
	19.05	55.11	8.94	19.97	54.77	51.82
12	18.92	56.68	9.26	18.89	57.26	53.37
	18.46	53.46	8.00	18.22	54.06	50.42
	18.52	52.53	7.30	19.07	52.28	47.89
	18.43	54.67	8.21	18.71	54.23	51.26
	18.87	59.01	10.06	18.52	58.42	56.5
	18.85	59.07	9.68	19.22	60.26	55.15
18	18.66	53.01	8.25	18.98	53.71	50.65
	18.48	53.68	7.91	18.68	54.66	50.07
	19.09	54.67	8.45	20.13	52.44	49.99
	19.12	55.82	8.88	19.61	55.24	51.39
	18.72	49.69	7.44	18.16	52.76	47.76
	18.54	49.12	7.51	18.89	52.07	48.54

APPENDIX D

CALIBRATION FOR VENTILATION RATE

APPENDIX D1. CALIBRATION FOR VENTILATION RATE (DUCT #1)

DUCT#1	DIGITAL OUTPUT (400-1700)						117.7-23 (V)	
POSITION	0	400	600	800	1000	1200	1600	2000
A	4.49	3.90	3.90	3.23	0.25	0.16	0.13	0.11
B	4.65	4.25	4.23	4.02	0.50	0.35	0.46	0.37
C	5.63	5.29	5.20	4.31	1.40	1.25	1.23	1.22
D	5.44	5.49	5.30	4.67	1.30	1.20	1.14	1.24
E	4.46	4.66	3.80	3.50	0.36	0.31	0.26	0.24
F	4.68	4.97	4.20	3.97	0.81	0.67	0.56	0.41
G	5.18	5.13	4.80	3.96	1.18	1.06	0.94	0.87
H	5.69	5.60	5.30	4.99	1.08	0.91	0.88	0.95
I	3.59	3.30	2.30	1.60	0.41	0.30	0.25	0.17
J	2.42	2.16	1.28	1.40	0.50	0.59	0.46	0.40
K	2.62	2.60	2.40	1.74	0.55	0.53	0.47	0.45
L	3.81	3.94	3.50	2.40	0.62	0.31	0.50	0.70
M	2.44	2.38	2.07	1.64	0.15	0.22	0.13	0.12
N	1.53	1.40	1.50	1.40	0.24	0.25	0.14	0.17
O	1.80	1.96	1.60	1.19	0.41	0.39	0.25	0.20
P	3.09	3.06	2.50	1.34	0.34	0.20	0.36	0.32
Q	1.78	1.91	1.70	1.17	0.22	0.16	0.14	0.13
R	1.53	1.57	1.30	1.58	0.18	0.14	0.12	0.14
S	1.39	1.47	1.00	0.95	0.26	0.18	0.15	0.14
T	2.48	2.29	1.80	0.70	0.27	0.25	0.10	0.14
SUM	68.70	67.33	59.68	49.76	11.03	9.43	8.67	8.49
AVG	3.44	3.37	2.98	2.49	0.55	0.47	0.43	0.42
Q(cms)	0.55	0.54	0.48	0.40	0.09	0.08	0.07	0.07

APPENDIX D2. CALIBRATION FOR VENTILATION RATE (DUCT #1)

DUCT#2	DIGITAL OUTPUT (110-1300)						117.2-24 (V)
POSITION 0	400	600	800	1000	1200	1600	2000
A 5.43	5.25	5.18	4.88	1.32	0.75	1.03	1.11
B 4.86	3.67	4.30	3.36	1.08	0.64	1.15	1.15
C 4.99	4.03	4.70	3.12	0.50	0.39	0.55	0.43
D 5.67	5.83	5.70	4.00	0.98	0.79	0.52	0.36
E 5.41	5.68	4.90	4.43	1.47	1.43	1.24	1.02
F 4.03	3.85	3.80	3.03	1.03	1.08	0.90	0.83
G 5.00	4.81	4.60	2.80	0.53	0.54	0.46	0.56
H 5.78	5.94	5.70	4.17	0.83	0.69	0.81	0.83
I 3.62	3.22	3.60	2.25	0.54	0.47	0.29	0.46
J 2.07	1.93	2.30	1.87	0.43	0.38	0.30	0.26
K 2.76	2.82	2.50	1.70	0.26	0.44	0.32	0.28
L 3.11	3.37	3.25	2.22	0.42	0.49	0.40	0.47
M 2.22	2.49	2.07	1.35	0.29	0.25	0.24	0.24
N 1.04	1.04	0.82	0.74	0.26	0.23	0.25	0.16
O 1.58	1.17	1.27	0.93	0.27	0.15	0.19	0.18
P 1.70	1.79	1.50	1.05	0.26	0.24	0.24	0.16
Q 1.32	1.01	0.88	0.35	0.25	0.15	0.18	0.10
R 0.82	0.79	0.73	0.34	0.30	0.13	0.15	0.13
S 1.59	1.68	1.30	0.47	0.16	0.12	0.15	0.14
T 1.49	1.73	1.40	0.38	0.21	0.14	0.12	0.13
SUM 64.49	62.10	60.50	43.44	11.39	9.50	9.49	9.00
AVG 3.22	3.11	3.03	2.17	0.57	0.48	0.47	0.45
Q(cms) 0.52	0.50	0.48	0.35	0.09	0.08	0.08	0.07

APPENDIX E.

PERFORMANCE OF THE RH CONTROL SYSTEM (BASED ON CPI)

CTL1C: D/A OUTPUT TO CONTROLLER #1

CTL2C: D/A OUTPUT TO CONTROLLER #2

Q1: VENTILATION RATE FOR CONTROLLER #1

Q2: VENTILATION RATE FOR CONTROLLER #2

WEEK1 DAY1

TIME(h)	RH1(%)	RH2(%)	RHattic	CTL1C	CTL2C	Q1 (m^3/s)	Q2 (m^3/s)
0	28.87	64.54	17.29	1700	1300	0.07	0.07
0.5	29.8	63.51	17.45	1200	1300	0.02	0.07
1	30.14	63.33	16.29	400	1300	0.53	0.07
1.5	29.6	66.4	17.37	1600	1300	0.07	0.07
2	30.49	67.42	17.86	400	1300	0.53	0.07
2.5	29.47	66.69	16.74	1000	100	0.17	0.55
3	28.98	66.76	17.73	1700	195	0.07	0.54
3.5	29.12	65.07	17.65	1100	100	0.10	0.55
4	28.77	66.19	16.28	1700	100	0.07	0.55
4.5	30.22	66.79	17.17	400	100	0.53	0.55
5	29.16	61.96	17.73	1700	1300	0.07	0.07
5.5	29.26	62.95	16.74	1700	1300	0.07	0.07
6	28.81	62.23	16.44	1295	1300	0.07	0.07
6.5	30.88	62	14.46	600	1300	0.43	0.07
7	30.54	67.79	14.26	400	500	0.53	0.46
7.5	29.13	63.93	16.63	1295	1300	0.07	0.07
8	29.2	63.76	16.9	1700	1300	0.07	0.07
8.5	29.36	66.29	15.95	1700	1195	0.07	0.08
9	29.15	63.94	16.28	1700	995	0.07	0.19
9.5	30.2	65.85	16.44	400	400	0.53	0.50
10	29.21	64.23	16.21	1000	1300	0.17	0.07
10.5	29.77	65.98	16.74	400	1195	0.53	0.08
11	30.35	63.42	16.95	400	1300	0.53	0.07
11.5	29.08	67.3	16.63	1700	1300	0.07	0.07
12	29.31	62.71	16.25	1700	1300	0.07	0.07
12.5	28.77	67.03	15.62	1700	195	0.07	0.54
13	29.46	67.2	12.79	900	100	0.24	0.55
13.5	28.89	67.43	15.51	1700	595	0.07	0.42
14	29.91	64.85	12.97	1700	1300	0.07	0.07
14.5	28.76	67.43	12.72	1700	895	0.07	0.25
15	30.91	65.85	14.42	400	100	0.53	0.55
15.5	29.38	65.24	14.98	1700	195	0.07	0.54
16	29.29	62.32	15.55	695	1300	0.38	0.07
16.5	29.04	64.03	16.78	1700	1300	0.07	0.07
17	29.68	62.21	17.02	1700	1300	0.07	0.07
17.5	30.01	63.93	16.94	400	1300	0.53	0.07
18	29.48	63.67	17.02	1700	1300	0.07	0.07
18.5	30.91	62.75	17.29	400	1300	0.53	0.07
19	29.78	67.1	16.9	1700	1300	0.07	0.07
19.5	30.82	65.01	17.05	400	100	0.53	0.55
20	29.16	64.9	17.13	1700	1300	0.07	0.07
20.5	29.63	62.05	17.02	1700	1300	0.07	0.07
21	29.36	63.6	17.02	1295	1300	0.07	0.07
21.5	28.48	66.46	17.17	1700	1300	0.07	0.07
22	30.11	65.65	16.51	400	395	0.53	0.50
22.5	28.2	65.92	17.02	1200	100	0.02	0.55
23	29.2	67.15	16.74	1700	100	0.07	0.55
23.5	30.13	64.26	16.4	400	1300	0.53	0.07

WEEK1 DAY2

0	62.64	29.45	15.73	1700	1300	0.07	0.07
0.5	64.53	30.29	16.21	1700	300	0.07	0.53
1	64.74	30.13	15.84	1700	100	0.07	0.55
1.5	67.26	29.1	15.95	1700	395	0.07	0.50
2	64.57	29.52	17.15	1700	100	0.07	0.55
2.5	66.19	29.2	16.37	400	1300	0.53	0.07
3	64.63	29.24	15.37	1700	100	0.07	0.55
3.5	65.11	29.94	18.69	1700	100	0.07	0.55
4	62.41	28.44	18.4	1700	100	0.07	0.55
4.5	66.12	29.75	18.95	400	100	0.53	0.55
5	63.25	29.94	17.63	1700	1300	0.07	0.07
5.5	63.35	29.84	15.12	1700	1300	0.07	0.07
6	65.41	29.49	15.22	1700	100	0.07	0.55
6.5	65.78	30.1	16.44	1700	100	0.07	0.55
7	66.42	30.03	16.78	1700	100	0.07	0.55
7.5	64.47	29.93	16.32	1700	1300	0.07	0.07
8	59.74	29.94	15.37	1700	100	0.07	0.55
8.5	64.36	29.08	15.47	1700	1300	0.07	0.07
9	58.97	29.43	16.21	1700	100	0.07	0.55
9.5	63.76	30.36	15.95	1700	595	0.07	0.42
10	67.64	31.15	16.95	400	100	0.53	0.55
10.5	63.28	30.13	15.15	600	100	0.43	0.55
11	64.36	30.23	13.06	1700	100	0.07	0.55
11.5	69.12	29.24	13.91	1095	1300	0.10	0.07
12	64.8	31.57	12.97	1700	200	0.07	0.54
12.5	62.51	28.26	14.73	1700	1000	0.07	0.19
13	61.02	31.11	14.98	1700	700	0.07	0.36
13.5	65.14	29.37	13.91	400	1300	0.53	0.07
14	60.01	31.02	12.12	1700	100	0.07	0.55
14.5	64.3	30.7	12.54	1700	100	0.07	0.55
15	67.94	31.76	15.51	400	1300	0.53	0.07
15.5	68.82	29.84	13.96	1700	100	0.07	0.55
16	61.26	29.91	16.25	1700	1300	0.07	0.07
16.5	64.03	29.71	14.73	1700	1300	0.07	0.07
17	66.35	29.65	14.29	1700	100	0.07	0.55
17.5	66.66	31.25	14.63	1700	100	0.07	0.55
18	67.77	30.77	14.94	400	100	0.53	0.55
18.5	66.42	30.9	15.19	1700	100	0.07	0.55
19	60.05	31.73	16.52	1700	100	0.07	0.55
19.5	66.39	30.03	17.05	895	100	0.24	0.55
20	63.79	30.29	17.97	1700	1300	0.07	0.07
20.5	65.34	31.18	18.56	595	100	0.44	0.55
21	66.25	30.38	17.94	400	100	0.53	0.55
21.5	65.68	28.57	18.69	1700	100	0.07	0.55
22	62.37	31.28	18.31	1700	100	0.07	0.55
22.5	63.12	29.97	18.47	1700	100	0.07	0.55
23	63.55	29.27	19.3	1700	100	0.07	0.55
23.5	63.01	28.63	18.69	1700	1300	0.07	0.07

WEEK2 DAY 1

TIME(h)	RH1(%)	RH2(%)	RHattic	CTL1C	CTL2C	Q1 (m^3/s)	Q2 (m^3/s)
0	63.72	30.3	14.42	1700	100	0.07	0.55
0.5	63.68	29.68	14.17	1700	100	0.07	0.55
1	66.93	29.91	13.47	1700	1000	0.07	0.19
1.5	65.02	29.05	14.76	400	1300	0.53	0.07
2	66.93	30.13	14.42	400	1200	0.53	0.08
2.5	67.88	30.8	14.17	400	100	0.53	0.55
3	67.33	30.64	13.89	400	100	0.53	0.55
3.5	63.18	30.13	14.94	1700	700	0.07	0.36
4	67.61	29.68	15.19	500	100	0.49	0.55
4.5	65.98	30.45	15.4	400	100	0.53	0.55
5	63.85	31.06	15.08	1700	100	0.07	0.55
5.5	67.62	30.45	15.19	995	100	0.17	0.55
6	64.39	28.76	15.29	1700	900	0.07	0.25
6.5	65.04	29.46	15.58	400	1300	0.53	0.07
7	65.07	29.17	14.49	1195	800	0.03	0.31
7.5	67.77	28.95	16.1	400	600	0.53	0.41
8	64.03	30.9	14.29	1700	200	0.07	0.54
8.5	66.33	30.39	15.51	1700	1300	0.07	0.07
9	66.13	30.86	14.94	1195	100	0.03	0.55
9.5	65.28	29.3	15.99	400	600	0.53	0.41
10	63.65	30.07	16.17	1000	100	0.17	0.55
10.5	67.94	29.78	15.15	400	100	0.53	0.55
11	64.82	29.2	15.26	1700	800	0.07	0.31
11.5	63.76	30	15.05	1700	1300	0.07	0.07
12	64.22	28.95	14.84	1700	1300	0.07	0.07
12.5	63.91	29.05	15.15	1700	900	0.07	0.25
13	67.65	28.98	15.03	1000	800	0.17	0.31
13.5	67.81	30.74	14.7	400	500	0.53	0.46
14	65.52	30.67	14.91	400	100	0.53	0.55
14.5	66.88	32.04	14.59	400	400	0.53	0.50
15	65.81	29.4	14.29	1700	100	0.07	0.55
15.5	63.76	30	14.49	400	100	0.53	0.55
16	66.53	28.25	14.19	400	1300	0.53	0.07
16.5	67.01	29.14	14.7	400	1300	0.53	0.07
17	65.12	29.78	14.19	400	100	0.53	0.55
17.5	67.04	30.07	14.29	695	1300	0.38	0.07
18	63.83	29.65	14.84	1700	100	0.07	0.55
18.5	67.87	30.13	14.49	1700	100	0.07	0.55
19	66.01	29.56	15.19	400	100	0.53	0.55
19.5	63.84	29.08	15.84	1700	1300	0.07	0.07
20	60.96	28.63	16.1	1700	1300	0.07	0.07
20.5	63.11	29.59	15.1	1700	100	0.07	0.55
21	64.64	29.75	16.32	1700	100	0.07	0.55
21.5	62.11	29.94	15.43	1700	100	0.07	0.55
22	62.32	29.62	16.1	1700	800	0.07	0.31
22.5	63.5	29.08	17.41	1700	600	0.07	0.41
23	63.13	30.8	16.93	1700	100	0.07	0.55
23.5	61.03	30.86	18.15	1700	100	0.07	0.55

WEEK2 DAY2

0	29.04	66.21	18.19	400	1300	0.53	0.07
0.5	29.96	64.49	17.65	1200	1300	0.02	0.07
1	30.42	65.36	18.19	1100	1300	0.10	0.07
1.5	30.01	62.75	18.01	500	1300	0.49	0.07
2	29.08	62.32	17.32	1700	1300	0.07	0.07
2.5	29.69	64.03	18.19	1700	1300	0.07	0.07
3	29.93	66.28	17.67	1700	100	0.07	0.55
3.5	29.31	63.13	17.82	1700	1300	0.07	0.07
4	30.96	67.67	17.78	400	1300	0.53	0.07
4.5	29.07	62.98	17.53	1700	1300	0.07	0.07
5	29.44	63.89	17.01	1700	1100	0.07	0.13
5.5	28.99	66.87	16.94	1400	100	0.07	0.55
6	30.01	65.38	17.38	400	1300	0.53	0.07
6.5	29.4	65.63	17.02	1700	100	0.07	0.55
7	30.92	63.05	16.94	900	1300	0.24	0.07
7.5	29.17	63.1	16.59	1700	1300	0.07	0.07
8	30.33	63.82	16.32	1700	1300	0.07	0.07
8.5	28.75	64.6	16.32	1700	1300	0.07	0.07
9	29.57	61.98	15.87	1700	1300	0.07	0.07
9.5	30.6	63.25	15.76	400	1300	0.53	0.07
10	29.47	61.6	15.92	1700	1300	0.07	0.07
10.5	28.68	63.6	16.02	1700	1300	0.07	0.07
11	30.26	63.96	15.68	1000	600	0.17	0.41
11.5	31.04	62.35	15.71	400	1300	0.53	0.07
12	28.93	61.6	15.07	1700	1300	0.07	0.07
12.5	29.68	64.89	15.73	1700	1300	0.07	0.07
13	30.12	66.84	15.99	700	1300	0.38	0.07
13.5	29.23	64.28	16.1	500	1300	0.49	0.07
14	29.9	67.23	16.21	1700	1300	0.07	0.07
14.5	30.04	65.12	16.32	600	1300	0.43	0.07
15	29.36	64.62	16.94	1700	1300	0.07	0.07
15.5	28.47	64.78	17.02	1300	1300	0.07	0.07
16	29.91	66.1	17.41	1700	100	0.07	0.55
16.5	28.53	62.37	16.94	1700	1300	0.07	0.07
17	30.31	62.1	17.04	1700	1300	0.07	0.07
17.5	29.64	61.53	16.7	400	1300	0.53	0.07
18	28.94	62.51	16.83	1700	1300	0.07	0.07
18.5	31.17	62.64	17.41	400	1300	0.53	0.07
19	30.21	62.91	18.31	400	1300	0.53	0.07
19.5	29.12	63.9	18.44	400	1300	0.53	0.07
20	30.23	62.7	18.69	400	695	0.53	0.37
20.5	29.58	62.37	19.02	1700	1300	0.07	0.07
21	28.55	62.36	19.34	1700	1300	0.07	0.07
21.5	28.73	63.63	19.25	1700	1300	0.07	0.07
22	28.16	62.07	19.79	1700	1300	0.07	0.07
22.5	28.2	64.4	18.86	1700	1300	0.07	0.07
23	30.76	63.08	19.08	400	1300	0.53	0.07
23.5	29.37	64.26	19.12	400	1300	0.53	0.07

WEEK3 DAY1

TIME(h)	RH1(%)	RH2(%)	RHattic	CTL1C	CTL2C	Q1 (m^3/s)	Q2 (m^3/s)
0	28.87	66.71	16.69	1700	100	0.07	0.55
0.5	29.84	62.61	15.06	1700	1300	0.07	0.07
1	28.16	64.3	16.25	1700	1300	0.07	0.07
1.5	28.04	64.77	16.62	1700	1300	0.07	0.07
2	29.24	62.21	16.69	1200	1300	0.02	0.07
2.5	28.86	63.82	16.32	1000	1300	0.17	0.07
3	29.91	65.71	15.73	1700	100	0.07	0.55
3.5	28.25	63.99	14.28	1700	1300	0.07	0.07
4	30.2	61.53	16.18	700	1300	0.38	0.07
4.5	29.11	64.8	16.8	1700	1300	0.07	0.07
5	28.77	65.17	15.78	1700	1300	0.07	0.07
5.5	30.63	64.36	16.58	400	1300	0.53	0.07
6	28.52	65.56	16.47	1700	1300	0.07	0.07
6.5	29.87	66.98	15.78	1700	1300	0.07	0.07
7	31.02	64.57	16.07	1300	1300	0.07	0.07
7.5	30.61	64.5	16.41	1295	1300	0.07	0.07
8	29.28	65.11	16.3	1700	100	0.07	0.55
8.5	29.65	65.31	16.45	1700	1300	0.07	0.07
9	28.88	66.02	16.3	1700	100	0.07	0.55
9.5	29.25	63.96	17.04	1700	1300	0.07	0.07
10	28.47	63.18	17.16	1700	1300	0.07	0.07
10.5	28.15	64.67	17.33	1700	1300	0.07	0.07
11	29.78	62.1	17.7	600	1300	0.43	0.07
11.5	30.12	63.08	17.04	400	1300	0.53	0.07
12	28.22	63.76	17.45	400	1300	0.53	0.07
12.5	29.94	62.31	17.41	400	759	0.53	0.33
13	29.62	65.81	17.57	400	1300	0.53	0.07
13.5	30.67	61.53	18.2	700	1300	0.38	0.07
14	29.73	63.62	17.95	400	1300	0.53	0.07
14.5	30.13	63.89	17.82	400	1300	0.53	0.07
15	29.87	64.26	17.16	400	1300	0.53	0.07
15.5	30.13	63.05	17.45	400	1300	0.53	0.07
16	29.58	62.64	17.08	400	495	0.53	0.46
16.5	29.36	63.18	16.1	695	1300	0.38	0.07
17	29.59	64.84	16.92	1700	1300	0.07	0.07
17.5	29.5	65.65	17.18	1700	595	0.07	0.42
18	29.37	64.97	16.41	500	1300	0.49	0.07
18.5	28.7	63.35	16.47	1700	1300	0.07	0.07
19	29.38	61.53	15.25	400	1300	0.53	0.07
19.5	27.83	64.53	15.99	600	1300	0.43	0.07
20	28.55	63.9	16.3	400	1300	0.53	0.07
20.5	28.25	64.16	16.07	400	1300	0.53	0.07
21	30.71	64.23	15.95	700	1200	0.38	0.08
21.5	28.31	62.1	16.45	400	1300	0.53	0.07
22	29.05	63.69	16.41	1700	1300	0.07	0.07
22.5	29.96	62.1	16.18	400	1300	0.53	0.07
23	28.31	65.34	16.3	1700	1300	0.07	0.07
23.5	29.21	62.1	16.07	1700	1300	0.07	0.07

WEEK3 DAY2

0	64.01	31.65	16.45	1700	100	0.07	0.55
0.5	67.41	30.54	16.57	400	100	0.53	0.55
1	65.19	29.65	16.01	595	700	0.44	0.36
1.5	66.85	30.86	16.41	400	100	0.53	0.55
2	68.42	31.13	16.69	400	100	0.53	0.55
2.5	65.22	30.32	16.1	1700	100	0.07	0.55
3	66.4	30.61	17.45	1300	500	0.07	0.46
3.5	67.14	29.95	16.18	400	100	0.53	0.55
4	65.05	30.93	16.84	400	100	0.53	0.55
4.5	63.8	30.22	16.45	1700	100	0.07	0.55
5	66.9	31.09	16.43	400	100	0.53	0.55
5.5	65.25	29.66	16.69	1700	1300	0.07	0.07
6	61.88	30.52	17.33	1700	300	0.07	0.53
6.5	66.1	28.5	17.86	1700	100	0.07	0.55
7	64.78	30.56	16.69	400	100	0.53	0.55
7.5	61.41	29.39	17.7	1700	100	0.07	0.55
8	63.03	30.67	17.33	1700	700	0.07	0.36
8.5	64.85	30.48	17.86	1700	100	0.07	0.55
9	65.32	28.55	17.74	400	1300	0.53	0.07
9.5	67.03	30.84	17.41	400	100	0.53	0.55
10	61.1	31.43	17.45	1700	100	0.07	0.55
10.5	62.18	28.68	16.18	1700	1300	0.07	0.07
11	67.01	30.67	17.45	1700	100	0.07	0.55
11.5	67.99	29.45	17.37	1700	100	0.07	0.55
12	65.69	32.36	16.96	400	700	0.53	0.36
12.5	66.81	31.1	17.33	400	1300	0.53	0.07
13	65.29	29.54	17.08	1700	100	0.07	0.55
13.5	66.08	29.28	17.16	1700	800	0.07	0.31
14	65.89	31.44	16.92	595	100	0.44	0.55
14.5	66.01	29.31	17.08	400	100	0.53	0.55
15	67.55	31.96	16.96	400	100	0.53	0.55
15.5	66.16	30.62	16.45	400	100	0.53	0.55
16	66.21	30.54	16.69	400	100	0.53	0.55
16.5	64.81	29.42	16.72	400	1100	0.53	0.13
17	64.28	29.61	15.28	400	100	0.53	0.55
17.5	64.14	30.58	14.89	1700	100	0.07	0.55
18	64.85	29.3	15.68	1700	300	0.07	0.53
18.5	67	31.1	16.04	400	100	0.53	0.55
19	64.01	30.69	15.95	1700	100	0.07	0.55
19.5	61.21	31.17	16.92	1700	100	0.07	0.55
20	61.24	28.75	17.12	1700	100	0.07	0.55
20.5	63.9	31.1	17.04	1700	100	0.07	0.55
21	66.81	31.23	17.53	1700	1300	0.07	0.07
21.5	67.87	30.3	17.18	400	100	0.53	0.55
22	63.8	28.94	17.76	1700	1300	0.07	0.07
22.5	61.37	30.12	17.95	1700	100	0.07	0.55
23	65.12	30.37	18.24	400	100	0.53	0.55
23.5	66.63	28.1	18.2	400	100	0.53	0.55

WEEK4 DAY1

TIM(h)	RH1(%)	RH2(%)	RHattic	CTL1C	CTL2C	Q1 (m^3/s)	Q2 (m^3/s)
0	30.2	65.75	17.27	400	100	0.53	0.55
0.5	29.3	64.57	18.17	1700	195	0.07	0.54
1	28.89	63.46	17.89	1700	1300	0.07	0.07
1.5	30.16	65.24	18.01	400	1300	0.53	0.07
2	29.59	62.6	17.54	1700	100	0.07	0.55
2.5	30.54	63.7	18.17	400	1295	0.53	0.07
3	31.76	64.45	18.29	400	100	0.53	0.55
3.5	30.42	66.58	17.46	400	100	0.53	0.55
4	29.59	61.82	17.39	1700	1300	0.07	0.07
4.5	30.27	63.23	17.54	400	1300	0.53	0.07
5	28.97	64.25	17.18	1700	1300	0.07	0.07
5.5	30.77	61.59	18.17	400	1300	0.53	0.07
6	30.54	58.85	16.63	400	1300	0.53	0.07
6.5	29.79	64.1	13.84	1700	1300	0.07	0.07
7	30.32	63.56	16.51	400	1300	0.53	0.07
7.5	30.24	64.18	16.74	400	1300	0.53	0.07
8	31.17	62.44	15.48	400	1300	0.53	0.07
8.5	28.96	61.06	17.65	1700	1300	0.07	0.07
9	29.97	62.63	17.2	1595	1300	0.07	0.07
9.5	29.93	65.4	16.41	1700	400	0.07	0.50
10	29.52	62.63	17.82	400	1300	0.53	0.07
10.5	29.88	62.01	18.01	1395	1300	0.07	0.07
11	30.03	61.55	16.64	400	1300	0.53	0.07
11.5	31.12	63.68	17.58	400	1300	0.53	0.07
12	30.13	63.63	15.03	400	300	0.53	0.53
12.5	30.64	62.62	14.87	500	1300	0.49	0.07
13	30.94	64.99	15.65	900	100	0.24	0.55
13.5	29.86	67.01	15.9	1700	100	0.07	0.55
14	28.85	64.49	14.79	600	1300	0.43	0.07
14.5	30.42	64.14	14.16	400	700	0.53	0.36
15	30.17	63.46	14.01	700	1300	0.38	0.07
15.5	27.98	65.39	14.19	1700	200	0.07	0.54
16	29.43	63.53	16.67	595	1300	0.44	0.07
16.5	29.97	62.38	17.46	400	1300	0.53	0.07
17	29.76	64.38	15.98	400	1300	0.53	0.07
17.5	29.45	60.37	17.5	400	1300	0.53	0.07
18	30.71	62.47	17.61	400	1300	0.53	0.07
18.5	30.34	66.74	17.01	400	100	0.53	0.55
19	30.23	63.42	16.89	400	1300	0.53	0.07
19.5	30.18	62.37	17.23	400	1300	0.53	0.07
20	29.46	62.67	17.44	400	1300	0.53	0.07
20.5	31.33	63.16	17.01	400	1300	0.53	0.07
21	30.89	65.26	17.34	595	100	0.44	0.55
21.5	29.68	64.83	17.63	400	1300	0.53	0.07
22	29.48	66.58	16.67	1700	495	0.07	0.46
22.5	30.64	62.63	16.19	400	1300	0.53	0.07
23	28.12	62.7	16.64	1700	1300	0.07	0.07
23.5	29.64	62.12	17.08	400	1300	0.53	0.07

WEEK4 DAY2

0	66.66	31.6	17.02	1600	300	0.07	0.53
0.5	65.92	29.83	19.08	400	395	0.53	0.50
1	66.19	30.52	18.15	400	100	0.53	0.55
1.5	64.13	29.71	18.4	1700	1300	0.07	0.07
2	64.87	30.87	20.94	1700	100	0.07	0.55
2.5	63.82	29.56	17.73	1700	1300	0.07	0.07
3	66.14	28.17	20.19	400	1300	0.53	0.07
3.5	65.88	30.14	19.65	400	100	0.53	0.55
4	65.54	29.56	19.08	1700	100	0.07	0.55
4.5	66.05	31.04	19.39	1495	100	0.07	0.55
5	64.3	28.76	16.4	1700	1300	0.07	0.07
5.5	65.51	30.13	15.01	400	100	0.53	0.55
6	66.29	28.46	15.58	600	1300	0.43	0.07
6.5	63.45	30.64	17.37	1700	100	0.07	0.55
7	65.75	29.46	16.67	1700	100	0.07	0.55
7.5	64.09	28.19	16.44	1700	1300	0.07	0.07
8	65.05	30.77	16.21	1700	295	0.07	0.53
8.5	66.32	28.89	14.37	600	1300	0.43	0.07
9	63.42	28.97	13.76	1700	1300	0.07	0.07
9.5	66.05	29.67	18.95	400	1300	0.53	0.07
10	62.85	30.12	15.34	1700	595	0.07	0.42
10.5	66.19	29.46	14.42	1600	1300	0.07	0.07
11	64.63	31.54	13.38	1095	100	0.10	0.55
11.5	64.5	31.09	13.79	1700	200	0.07	0.54
12	64.5	28.58	14.19	1700	1300	0.07	0.07
12.5	65.81	27.9	14.09	1700	1300	0.07	0.07
13	64.47	29.01	13.15	1700	1300	0.07	0.07
13.5	63.19	30.63	14.42	1700	100	0.07	0.55
14	62.06	29.89	11.9	1700	1300	0.07	0.07
14.5	63.59	28.23	19.17	1700	1300	0.07	0.07
15	62.37	31.09	14.16	1700	400	0.07	0.50
15.5	64.63	29.05	14.87	1700	1300	0.07	0.07
16	66.83	29.84	16.44	400	1300	0.53	0.07
16.5	65.11	30.43	16.32	1095	100	0.10	0.55
17	63.96	27.98	14.98	1700	1300	0.07	0.07
17.5	67.3	29.04	15.26	400	100	0.53	0.55
18	63.83	31.75	15.33	1700	100	0.07	0.55
18.5	64.8	29.28	20.06	895	100	0.24	0.55
19	62.51	28.268	18.52	1100	1300	0.10	0.07
19.5	66.63	29.18	19.08	1700	500	0.07	0.46
20	65.68	30.68	17.53	400	100	0.53	0.55
20.5	68.58	28.82	18.31	400	100	0.53	0.55
21	67.03	30.09	22.8	400	100	0.53	0.55
21.5	63.45	29.84	21.27	1700	1300	0.07	0.07
22	63.39	30.23	20.93	1700	100	0.07	0.55
22.5	65.11	28.22	20.93	400	1300	0.53	0.07
23	64.07	32.02	18.31	1700	1300	0.07	0.07
23.5	67.76	28.38	19.3	400	1300	0.53	0.07

WEEK5 DAY1

TIME(h)	RH1(%)	RH2(%)	RHattic	CTL1C	CTL2C	Q1 (m^3/s)	Q2 (m^3/s)
0	29.65	66.28	13.38	1600	1300	0.07	0.07
0.5	29.48	66.11	13.09	1700	695	0.07	0.37
1	30.12	62.11	14.53	400	1300	0.53	0.07
1.5	29.22	63.47	13.86	400	1300	0.53	0.07
2	29.79	62.52	13	1700	1300	0.07	0.07
2.5	30.51	63.87	14.53	1400	1300	0.07	0.07
3	30.04	63.17	14.32	1300	1300	0.07	0.07
3.5	29.56	67.54	13.79	1000	100	0.17	0.55
4	31.04	63.4	15.08	400	1300	0.53	0.07
4.5	30.87	62.78	13.7	400	1300	0.53	0.07
5	29.88	67.95	14.94	700	100	0.38	0.55
5.5	29.17	63.64	13.5	1700	1300	0.07	0.07
6	29.86	61.95	14.84	1700	1300	0.07	0.07
6.5	30.12	60.18	13.6	400	1300	0.53	0.07
7	28.91	66.59	15.84	400	1300	0.53	0.07
7.5	29.23	66.44	13.89	400	1300	0.53	0.07
8	30.82	66.91	16.1	700	1195	0.38	0.08
8.5	30.71	64.55	14.29	400	1300	0.53	0.07
9	29.85	61.18	15.62	800	1300	0.31	0.07
9.5	30.73	67.01	15.89	600	400	0.43	0.50
10	30.08	62.56	14.22	1700	1300	0.07	0.07
10.5	29.66	64.78	15.87	1700	1300	0.07	0.07
11	30.12	67.21	15.73	400	1300	0.53	0.07
11.5	29.09	64.49	15.29	600	1300	0.43	0.07
12	30.3	66.67	13.66	400	100	0.53	0.55
12.5	30.76	62.19	13.86	400	1300	0.53	0.07
13	31.23	64.11	14.63	400	100	0.53	0.55
13.5	28.28	65.41	14.91	1300	1300	0.07	0.07
14	29.7	61.48	13.57	600	1300	0.43	0.07
14.5	29.64	62.49	13.38	1700	1300	0.07	0.07
15	30.03	62.91	13.46	1300	1300	0.07	0.07
15.5	31.41	65.34	13.57	400	1300	0.53	0.07
16	29.71	62.47	13.84	400	1300	0.53	0.07
16.5	30.21	65.86	13.26	400	895	0.53	0.25
17	29.33	67	13.99	1700	195	0.07	0.54
17.5	30.45	63.22	12.69	800	1300	0.31	0.07
18	28.88	66.71	14.7	1700	1300	0.07	0.07
18.5	29.42	62.79	13.79	1700	400	0.07	0.50
19	30.28	63.33	14.19	500	1300	0.49	0.07
19.5	31.53	64.38	15.84	400	1300	0.53	0.07
20	30.05	66.64	14.36	400	1300	0.53	0.07
20.5	30.76	63.74	15.37	400	1300	0.53	0.07
21	28.57	64.28	14.94	1700	1300	0.07	0.07
21.5	31.56	66.07	15.99	1400	100	0.07	0.55
22	28.05	63.71	17.13	400	1300	0.53	0.07
22.5	28.91	67.42	16.44	1700	295	0.07	0.53
23	30.35	64.97	17.25	400	1300	0.53	0.07
23.5	28.88	66.23	17.13	1700	100	0.07	0.55

WEEK5 DAY2

0	62.11	29.72	16.94	1700	100	0.07	0.55
0.5	64.71	31.57	18.15	1700	100	0.07	0.55
1	66.2	30.23	17.78	1700	700	0.07	0.36
1.5	62.18	30.13	16.78	1700	100	0.07	0.55
2	65.18	29.91	17.86	400	100	0.53	0.55
2.5	64.55	30.26	17.29	1700	100	0.07	0.55
3	66.37	31.57	18.15	1300	100	0.07	0.55
3.5	64.1	30.51	17.17	1700	100	0.07	0.55
4	62.69	29.97	17.25	1700	100	0.07	0.55
4.5	64.47	29.97	17.25	1700	1100	0.07	0.13
5	65.72	29.68	17.29	1700	100	0.07	0.55
5.5	65.01	30	16.32	400	100	0.53	0.55
6	63.58	29.36	17.02	1700	1300	0.07	0.07
6.5	66.7	29.27	16.46	400	200	0.53	0.54
7	65.65	29.91	16.1	400	100	0.53	0.55
7.5	64.85	30	16.83	400	100	0.53	0.55
8	67.84	31.66	16.47	400	100	0.53	0.55
8.5	64.58	30.23	15.87	400	1200	0.53	0.08
9	63.66	31.09	16.1	600	100	0.43	0.55
9.5	62.82	29.27	15.4	1700	900	0.07	0.25
10	63.26	29.4	15.87	1700	1300	0.07	0.07
10.5	62.86	28.98	15.99	1700	700	0.07	0.36
11	62.32	30.29	15.87	1700	100	0.07	0.55
11.5	66.5	29.62	16.1	1700	100	0.07	0.55
12	62.42	30.58	16.02	1700	500	0.07	0.46
12.5	63.63	29.14	15.99	1700	1300	0.07	0.07
13	68.11	29.75	15.76	1700	100	0.07	0.55
13.5	62.72	30.48	16.21	400	1300	0.53	0.07
14	62.69	29.97	16.47	1700	100	0.07	0.55
14.5	66.29	29.36	15.88	1700	1300	0.07	0.07
15	62.69	28.92	16.67	1700	1200	0.07	0.08
15.5	65.55	29.56	16.32	1700	100	0.07	0.55
16	63.13	28.92	17.13	400	1300	0.53	0.07
16.5	64.31	30.64	17.05	1700	100	0.07	0.55
17	64.17	30.03	16.78	1700	100	0.07	0.55
17.5	64.98	30.03	16.7	1700	100	0.07	0.55
18	66.85	30.58	17.29	400	100	0.53	0.55
18.5	66.16	30.58	17.82	400	100	0.53	0.55
19	66.57	30.58	17.45	400	100	0.53	0.55
19.5	66.92	29.49	18.19	400	100	0.53	0.55
20	66	29.72	18.44	400	100	0.53	0.55
20.5	64	31.06	18.56	1700	100	0.07	0.55
21	64.74	30.29	18.34	1700	100	0.07	0.55
21.5	66.26	32.2	19.47	1700	100	0.07	0.55
22	64.51	30.35	19.65	1700	100	0.07	0.55
22.5	65.65	30.54	18.99	1700	100	0.07	0.55
23	69.16	30.35	18.69	400	100	0.53	0.55
23.5	67.41	30.39	19.39	400	100	0.53	0.55

WEEK6 DAY1

TIME(h)	RH1(%)	RH2(%)	RHattic	CTL1C	CTL2C	Q1 (m^3/s)	Q2 (m^3/s)
0	62.15	30.56	15.62	1700	100	0.07	0.55
0.5	64.44	30.13	15.47	400	100	0.53	0.55
1	67.78	29.27	15.52	400	100	0.53	0.55
1.5	64.75	29.44	15.73	1700	1200	0.07	0.08
2	67.08	29.71	15.73	500	100	0.49	0.55
2.5	65.76	29.71	15.84	400	100	0.53	0.55
3	68.05	29.81	14.92	400	100	0.53	0.55
3.5	61.68	29.75	15.36	1700	700	0.07	0.36
4	65.59	30.03	15.25	400	1300	0.53	0.07
4.5	64.85	29.43	15.36	400	100	0.53	0.55
5	62.96	29.54	15.69	1700	100	0.07	0.55
5.5	64.75	31.86	15.47	400	100	0.53	0.55
6	62.99	28.8	15.36	1700	1300	0.07	0.07
6.5	62.41	29.56	15.8	1700	1300	0.07	0.07
7	65.12	29.79	15.8	400	100	0.53	0.55
7.5	64.07	29.78	14.82	400	100	0.53	0.55
8	64.75	28.11	16.18	400	1300	0.53	0.07
8.5	65.25	29.22	15.95	1700	1300	0.07	0.07
9	67.58	29.03	16.57	1600	100	0.07	0.55
9.5	66.03	31.06	16.65	400	600	0.53	0.41
10	64.85	29.88	17.04	400	1300	0.53	0.07
10.5	62.25	29.34	17.16	1700	100	0.07	0.55
11	65.33	31.07	17.16	400	100	0.53	0.55
11.5	67.28	30.46	17.57	400	100	0.53	0.55
12	66.3	30.01	17.82	400	100	0.53	0.55
12.5	67.08	30.08	17.82	1700	900	0.07	0.25
13	64.88	30.18	17.41	600	500	0.43	0.46
13.5	66.52	30.97	16.18	1095	100	0.10	0.55
14	67.87	30.55	17.29	400	100	0.53	0.55
14.5	63.33	28.36	17.57	1700	1300	0.07	0.07
15	64.68	30.59	17.57	1700	600	0.07	0.41
15.5	65.32	28.63	15.73	400	1300	0.53	0.07
16	63.88	29.49	16.57	1700	1300	0.07	0.07
16.5	63.91	30.07	17.45	1700	100	0.07	0.55
17	67.25	31.67	16.96	1700	800	0.07	0.31
17.5	64.85	31.16	15.03	1700	100	0.07	0.55
18	62.42	30.33	14.82	1700	100	0.07	0.55
18.5	63.7	30.18	15.18	1700	100	0.07	0.55
19	66.1	30.93	14.68	400	100	0.53	0.55
19.5	63.74	30.38	16.07	1700	100	0.07	0.55
20	62.45	30	16.18	1700	100	0.07	0.55
20.5	65.25	30.36	16.18	1700	900	0.07	0.25
21	62.45	29.87	16.41	1700	1300	0.07	0.07
21.5	64.61	29.71	16.53	1700	800	0.07	0.31
22	65.12	29.97	14.82	1700	100	0.07	0.55
22.5	63.3	28.88	14.36	1700	1300	0.07	0.07
23	64.07	30.03	15.8	400	100	0.53	0.55
23.5	64.98	30.59	16.41	400	900	0.53	0.25

WEEK6 DAY2

0	27.61	61.8	14.71	1600	1300	0.07	0.07
0.5	28.86	62.04	15.47	1700	1300	0.07	0.07
1	28.79	63.83	16.33	1700	1300	0.07	0.07
1.5	30.23	63.18	14.82	400	1300	0.53	0.07
2	30.2	64.43	15.62	400	1300	0.53	0.07
2.5	29.43	62.78	16.57	1700	1300	0.07	0.07
3	29.56	64.03	16.22	1700	1300	0.07	0.07
3.5	28.98	62.91	16.45	1700	1300	0.07	0.07
4	29.08	63.69	15.73	400	1200	0.53	0.08
4.5	29.37	63.35	14.92	400	1300	0.53	0.07
5	28.35	63.35	15.18	1700	1300	0.07	0.07
5.5	28.34	64.08	16.57	1700	1300	0.07	0.07
6	31.28	64.9	16.3	400	1300	0.53	0.07
6.5	30.9	62.1	16.62	400	1300	0.53	0.07
7	30.1	65.98	17	400	1300	0.53	0.07
7.5	29.08	63.55	17.41	400	1300	0.53	0.07
8	29.49	63.82	16.96	1700	1300	0.07	0.07
8.5	28.95	60.86	16.1	1700	1300	0.07	0.07
9	30.64	65.31	16.84	400	1295	0.53	0.07
9.5	29.97	63.89	17.08	1500	1300	0.07	0.07
10	31.25	65.31	17.57	400	1300	0.53	0.07
10.5	29.33	62.68	16.57	1700	1300	0.07	0.07
11	27.99	64.03	16.41	1700	1300	0.07	0.07
11.5	29.14	63.96	15.84	1700	1300	0.07	0.07
12	28.7	64.13	16.41	1700	1300	0.07	0.07
12.5	28.22	61.36	16.92	1500	1300	0.07	0.07
13	30.01	60.45	17.52	400	1300	0.53	0.07
13.5	28.94	60.38	16.1	1700	1300	0.07	0.07
14	28.12	65.54	16.1	1700	1300	0.07	0.07
14.5	27.64	63.39	16.8	1700	1300	0.07	0.07
15	29.78	60.86	16.96	1700	1300	0.07	0.07
15.5	29.49	64.74	17.33	800	1300	0.31	0.07
16	31.18	63.82	15.84	400	1300	0.53	0.07
16.5	29.43	62.54	16.1	400	1300	0.53	0.07
17	30.43	66.42	18.2	400	100	0.53	0.55
17.5	28.36	65.27	17.98	1700	1300	0.07	0.07
18	28.41	65.85	19.03	1700	1300	0.07	0.07
18.5	30.17	63.05	16.8	400	1300	0.53	0.07
19	29.3	62.04	15.07	1600	1300	0.07	0.07
19.5	31.02	64.13	13.46	400	1300	0.53	0.07
20	28.09	66.56	16.22	1500	1300	0.07	0.07
20.5	29.46	63.96	18.11	1700	1300	0.07	0.07
21	29.62	62.34	16.1	400	1300	0.53	0.07
21.5	29.53	64.43	17.7	1700	1300	0.07	0.07
22	28.92	63.72	16.8	1700	1300	0.07	0.07
22.5	30.2	63.59	17.16	400	1300	0.53	0.07
23	29.21	65.65	16.96	400	1300	0.53	0.07
23.5	29.46	63.66	16.96	1700	1300	0.07	0.07